Lake Dynamics

"Limnology 101"

March 31st, 2017

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- **Mike Adam: Lake County Health Department**
- **Joe Bartletti: Prairie Engineers**
- **Bryan Cross: Prairie Engineers**

What makes a lake and what types of lakes are there?

Lake Morphology and Morphometry

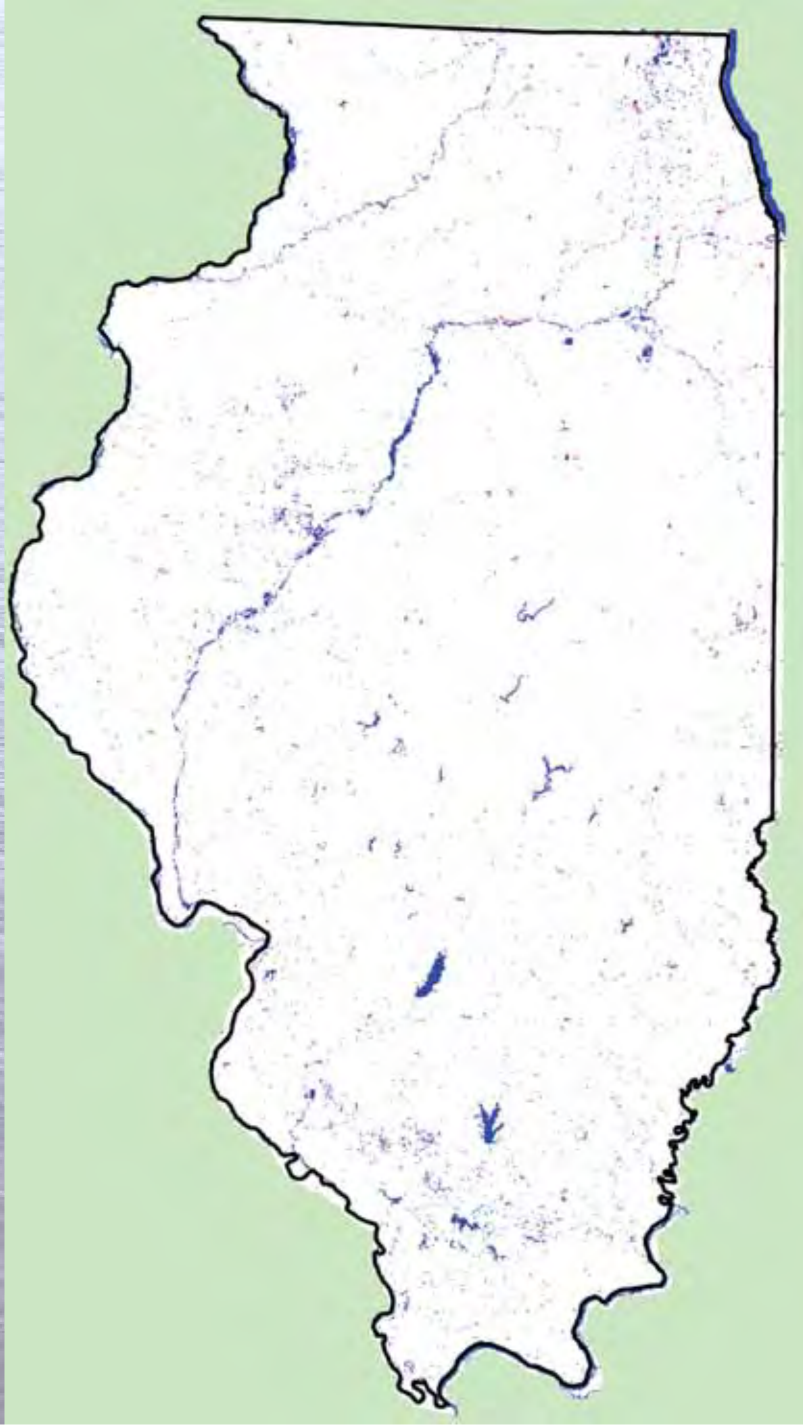
Major Lake Types

G. E. Hutchinson, father of modern limnology, identified 76 ways lakes may form

- Glacial – ice scour, ice block, morainal
- Tectonic – geologic processes: crustal movements, uplifted sea beds
- Volcanic – caldera
- Reservoirs – dams on rivers and streams
- Oxbows – remnant river channels
- Backwater – river connectivity
- Modified Glacial – water levels altered
- Excavated – Gravel Pits, Strip Mines, etc.
- Other – Beaver dams, Solution (Karst), etc.

Lakes in Illinois include:

- Glacial & Modified Glacial Lakes
- Reservoirs
- Farm Ponds
- Strip Mine Lakes
- Gravel Pit Lakes
- Oxbow Lakes
- Backwater Lakes
- and one of the Great Lakes - Lake Michigan



Glacial, Gravel Pit, Strip Mine, & Backwater

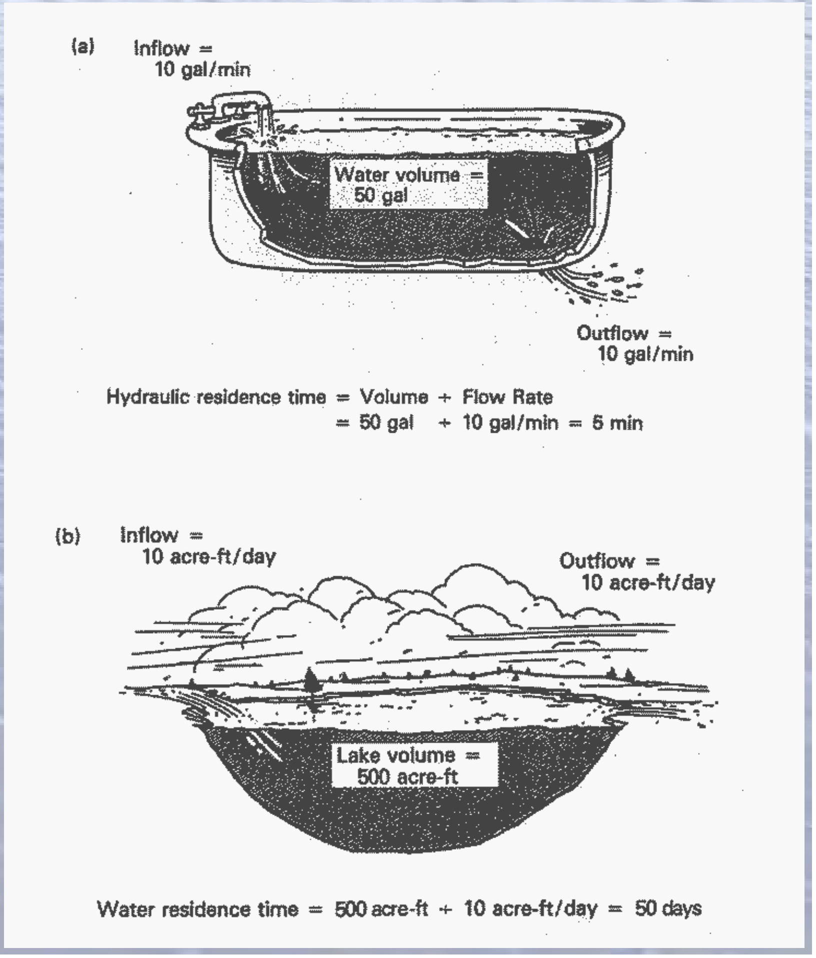
A Lake is a *Reflection* of its Watershed

- Watershed: the land area that drains into a body of water
- Rainfall collects within the lake basin
- Water runs downhill – both over and under ground
- Runoff carries nutrients, soil, & other pollutants with it
- Watershed slope, soils, vegetation, land use & geology affect runoff

Hydraulic Residence Time (HRT)

- The average time required to completely renew a lake's water volume

HRT (years) = lake volume (acre-ft) / mean outflow (acre-ft/yr)

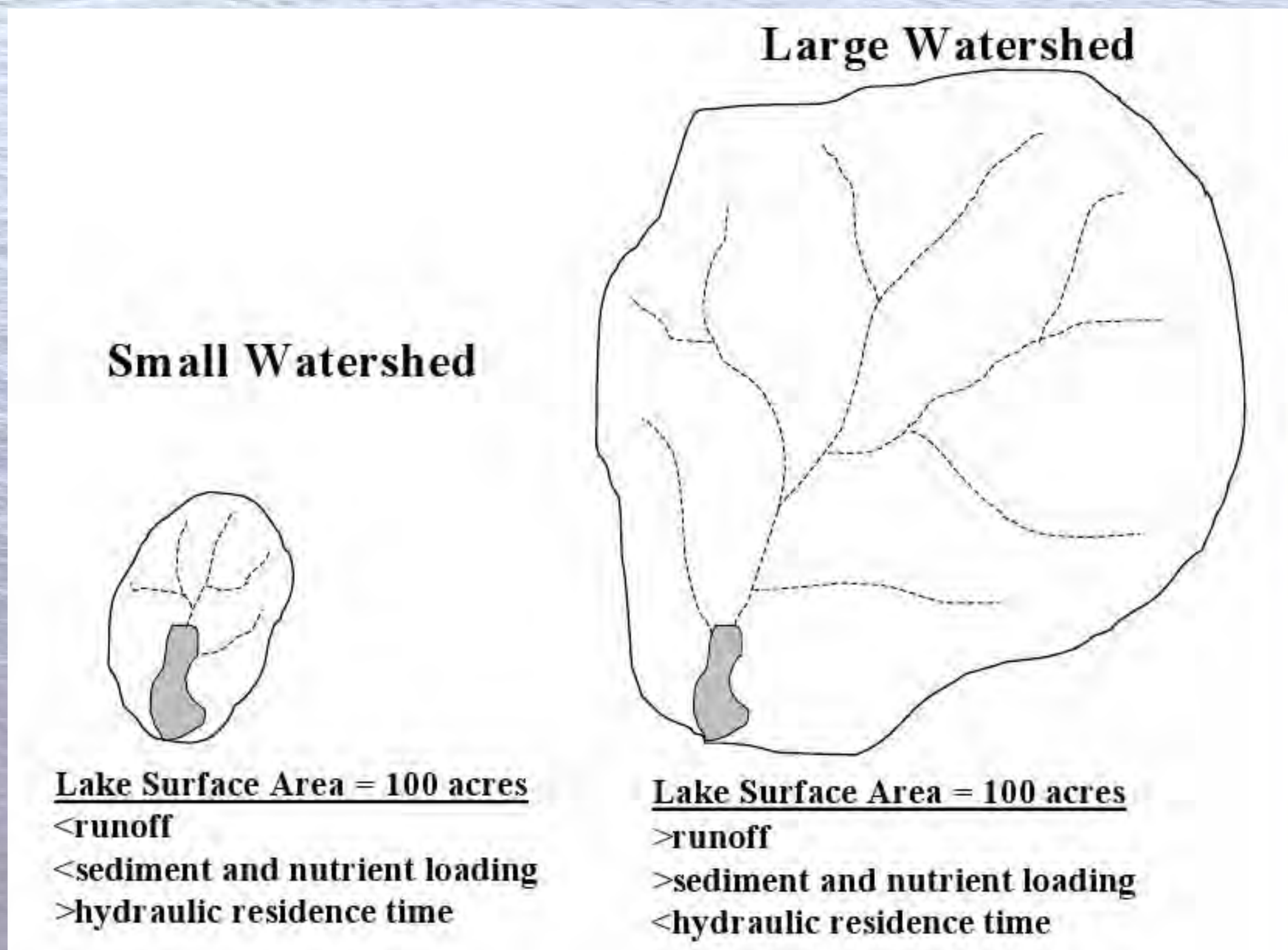


Lake volume and its effect on hydraulic residence time

- A large, deep lake with moderate inflow has a long hydraulic residence time; whereas, a small, shallow lake with a similar inflow will have a short residence time

Flushing rate = 1 / HRT

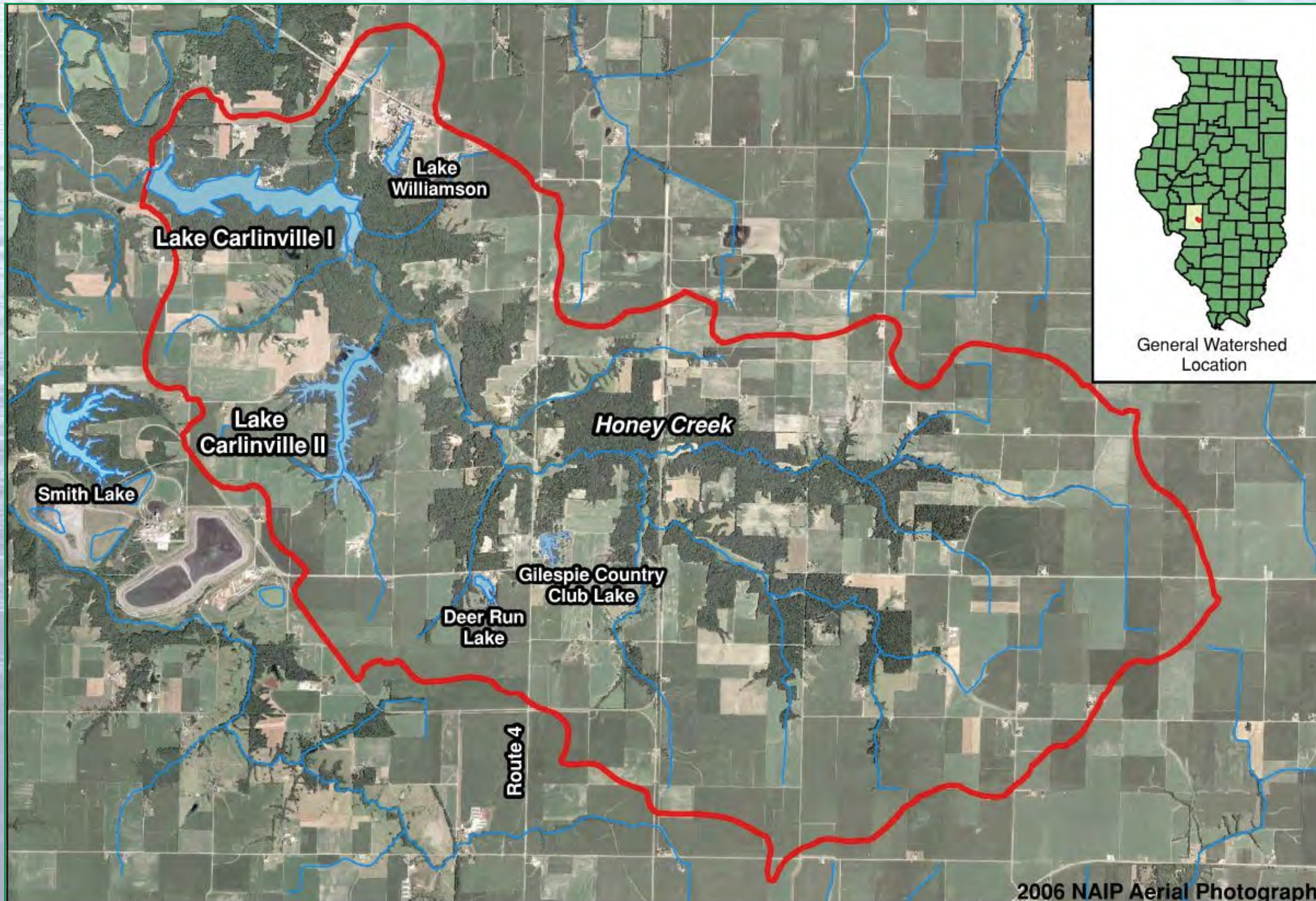
Watershed size and its effect on hydraulic residence time



Lakes with Small Watersheds (e.g., glacial lakes)

Lakes with Large Watersheds (e.g., reservoirs)

Large Watershed = Lots of Inflow

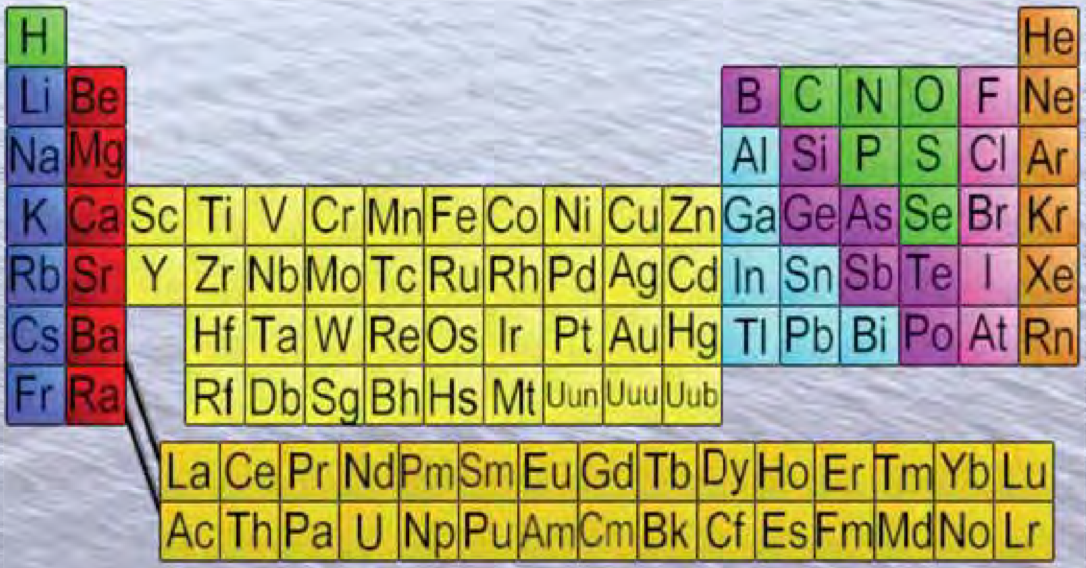


How does the type of lake impact it?

How does the type of lake impact it?

Nutrients

- Major Players
  - Oxygen
  - Hydrogen
  - Carbon
  - Nitrogen
  - Phosphorus



- Others
  - Calcium, Iron, Magnesium, Manganese, Potassium, Silicon, Sodium, Sulfate
  - Chloride

Nutrients

- Phosphorus
  - Total phosphorus
  - Dissolved/Soluble phosphorus
- Nitrogen
  - Organic
  - Inorganic

Trophic States

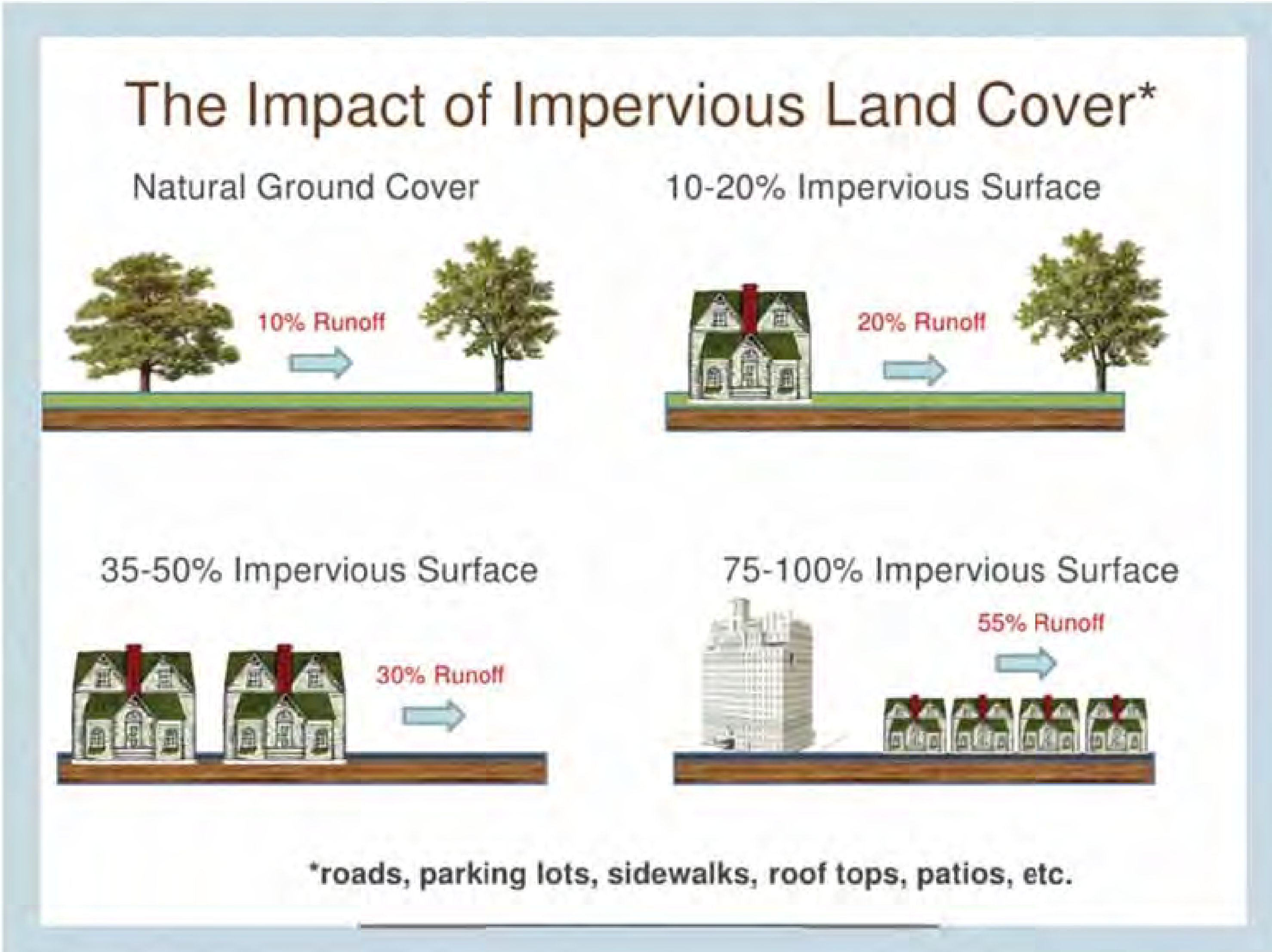
- Primarily determined by nutrients (i.e., Phosphorus)
  - Most lakes in IL are eutrophic
  - Carlson’s Trophic State Index

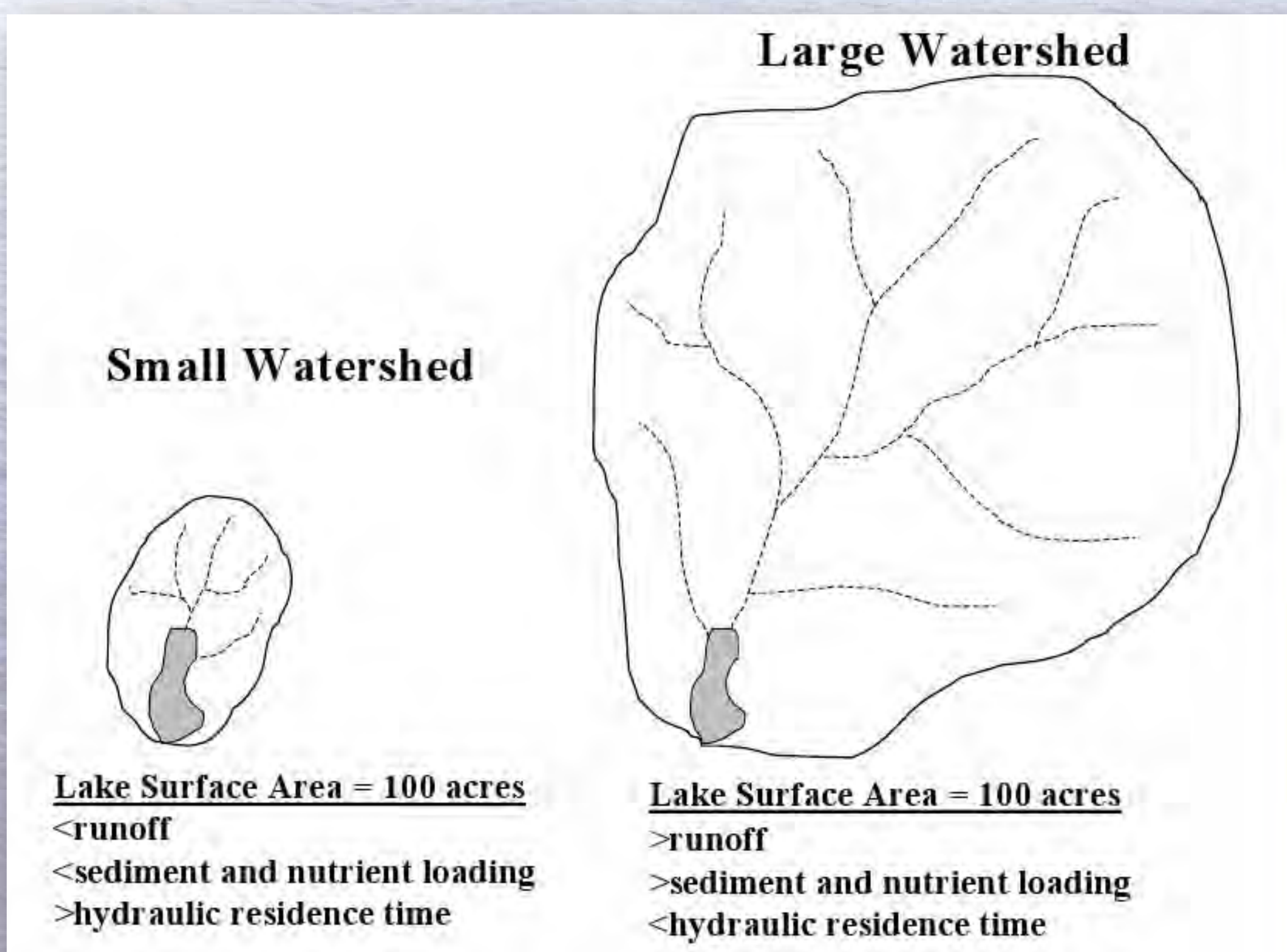
<30 TSI

30-49 TSI

50-70 TSI

> 70 = Hypereutrophic


The Impact of Impervious Land Cover*
Natural Ground Cover
10% Runoff
10-20% Impervious Surface
20% Runoff
35-50% Impervious Surface
30% Runoff
75-100% Impervious Surface
55% Runoff
*roads, parking lots, sidewalks, roof tops, patios, etc.



Large Watershed
Small Watershed
Lake Surface Area = 100 acres
<runoff
<sediment and nutrient loading
>hydraulic residence time
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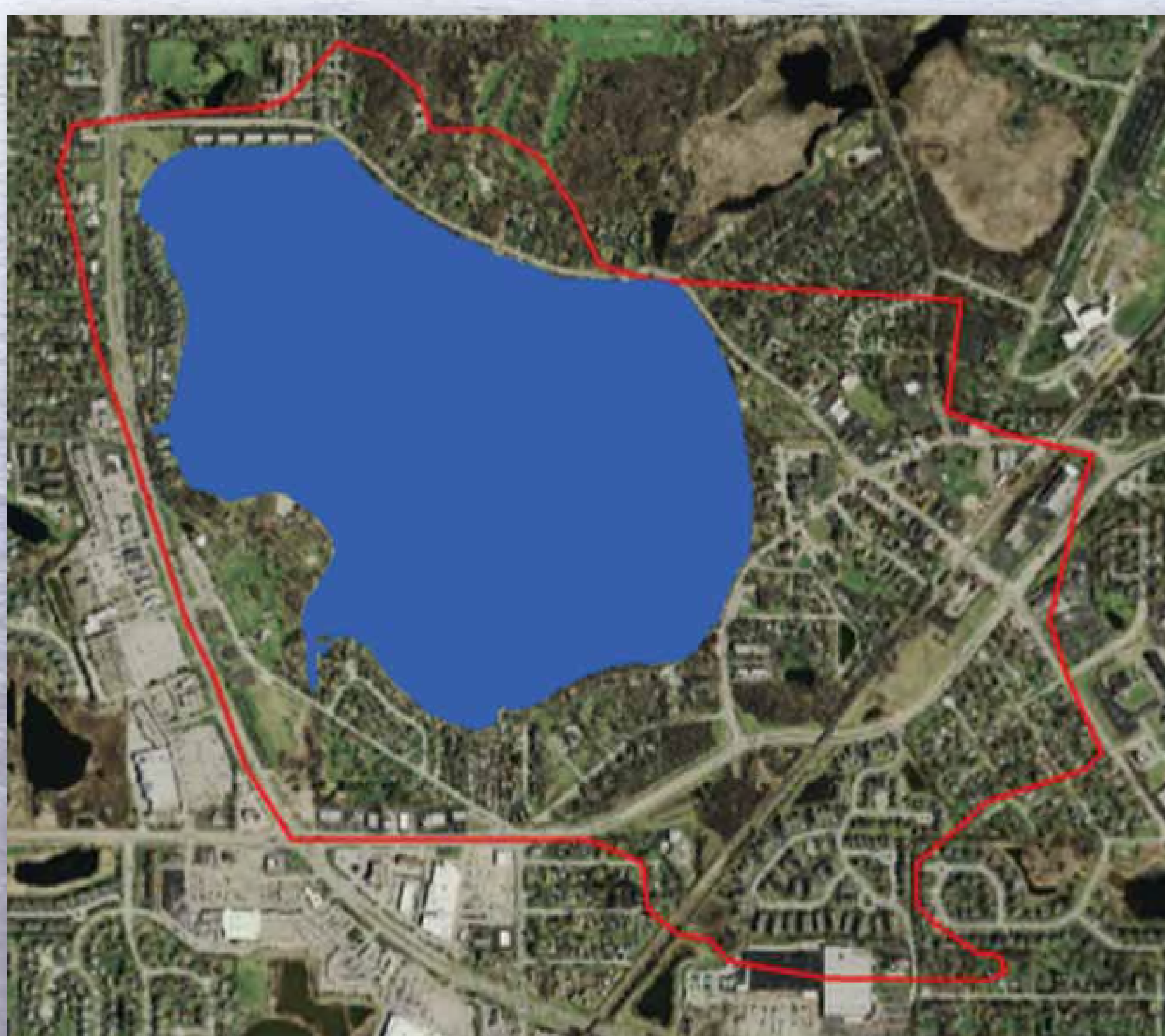
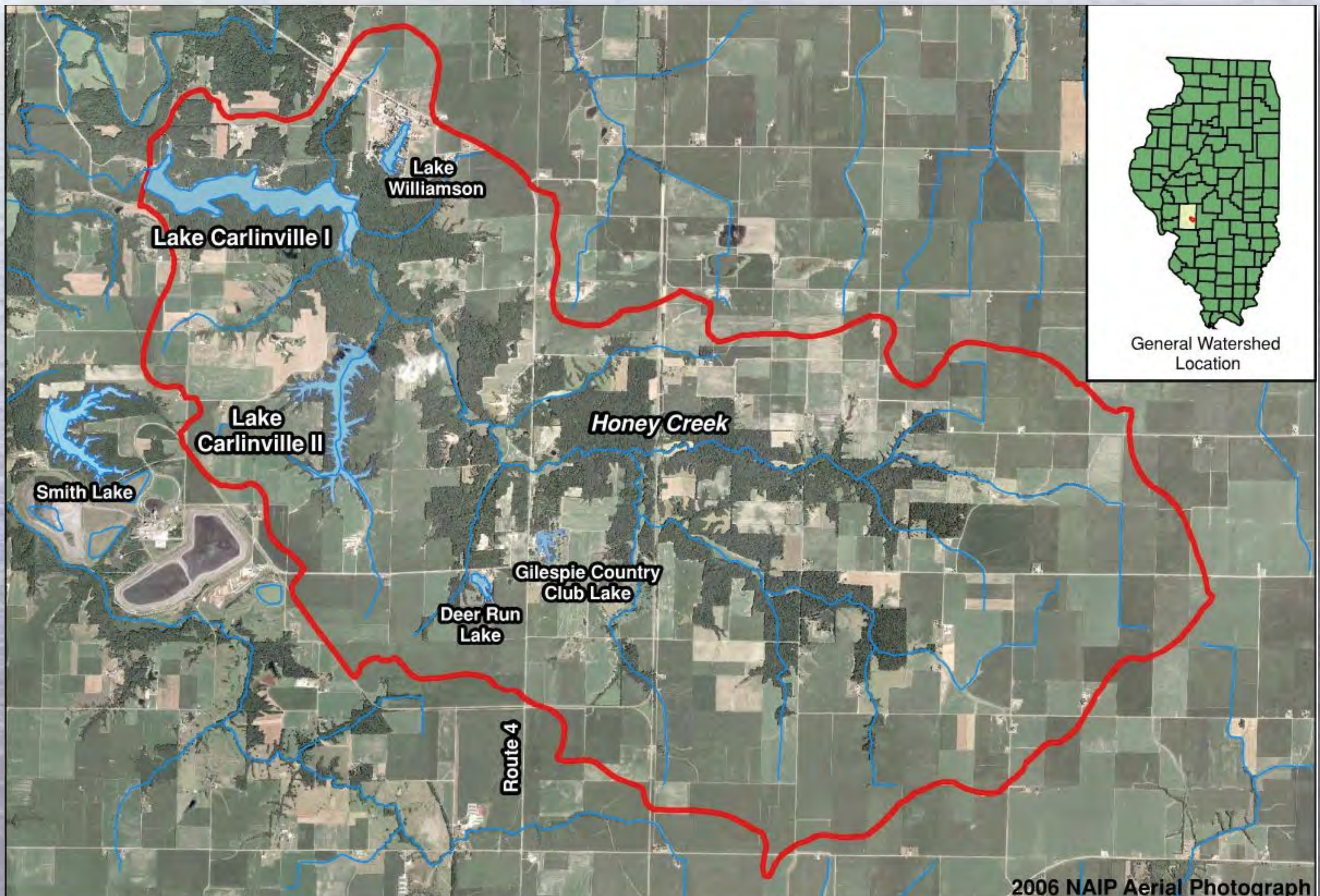
>runoff
>sediment and nutrient loading
<hydraulic residence time




Lake Williamson
Lake Carlinville I
Lake Carlinville II
Smith Lake
Honey Creek
Gilespie Country Club Lake
Deer Run Lake
Route 4
General Watershed Location
2006 NAIP Aerial Photograph

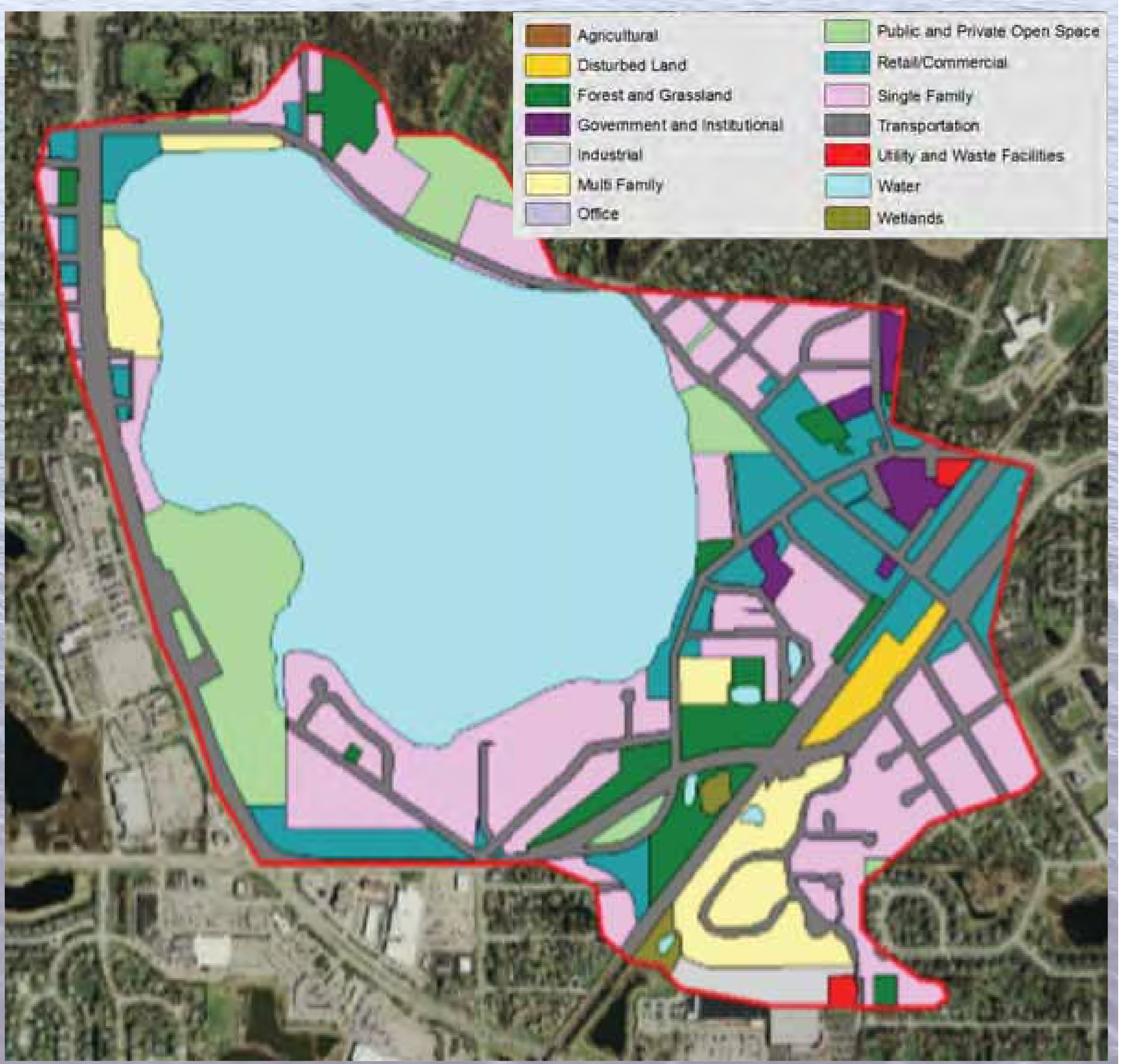
Lake Zurich Land Use

Landuse

- Water: 38.2%
- Single Family: 19.8%
- Transportation: 14.8%

Runoff

- Transportation: 39.5%
- Retail/Commercial 21% (only 7.8% of watershed)
- Single Family (18.9%)





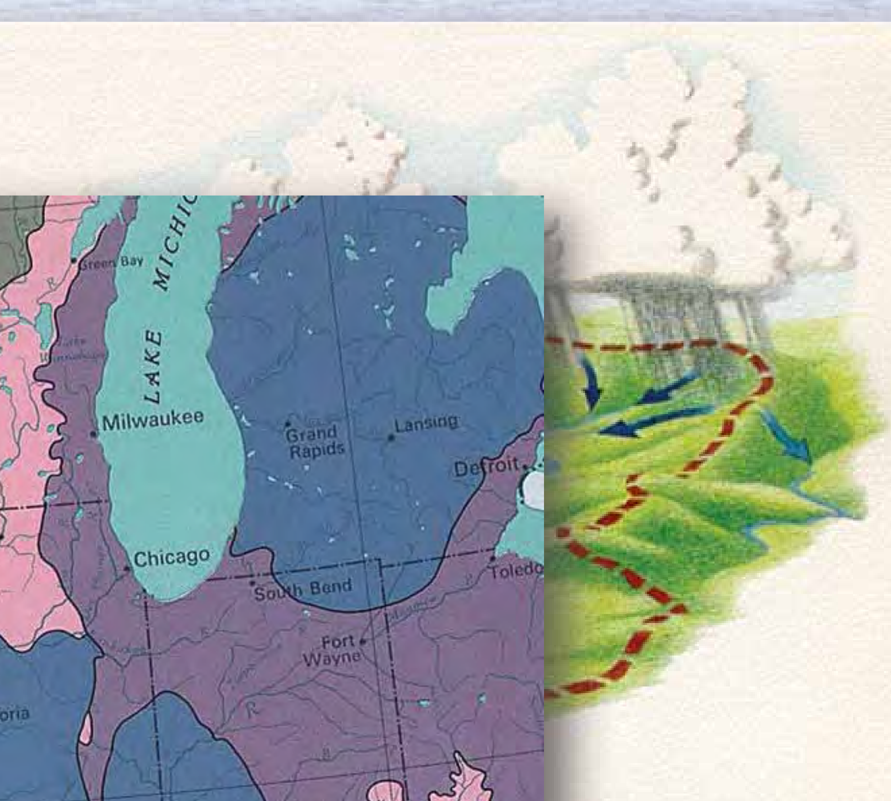


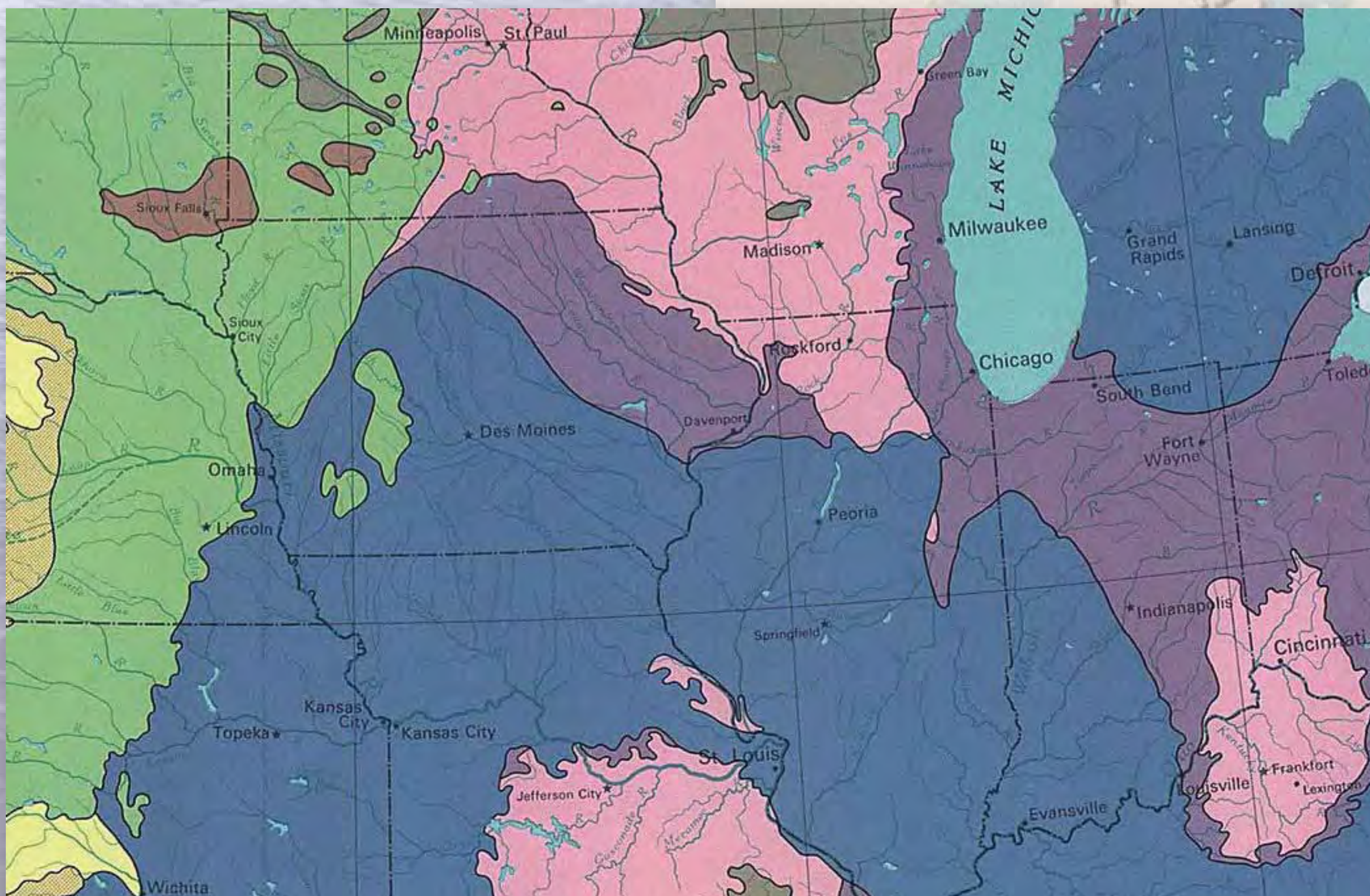
PET WASTE
TRANSMITS DISEASE
Leash-Curb and Clean Up
After Your Dog
IT'S THE LAW!
$25 TO $200 FINE


PLEASE DON'T
FEED THE WATERFOWL!
Waterfowl may become dependent on your
handouts and their feces may cause beach closures.
WATERFOWL ARE NOT PETS!

How does the location of the lake impact it?

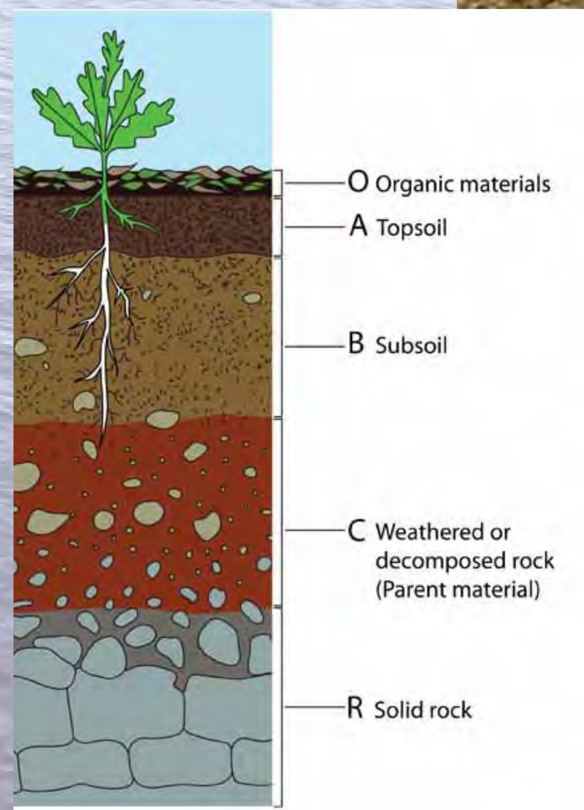
How does the location of the lake impact it?

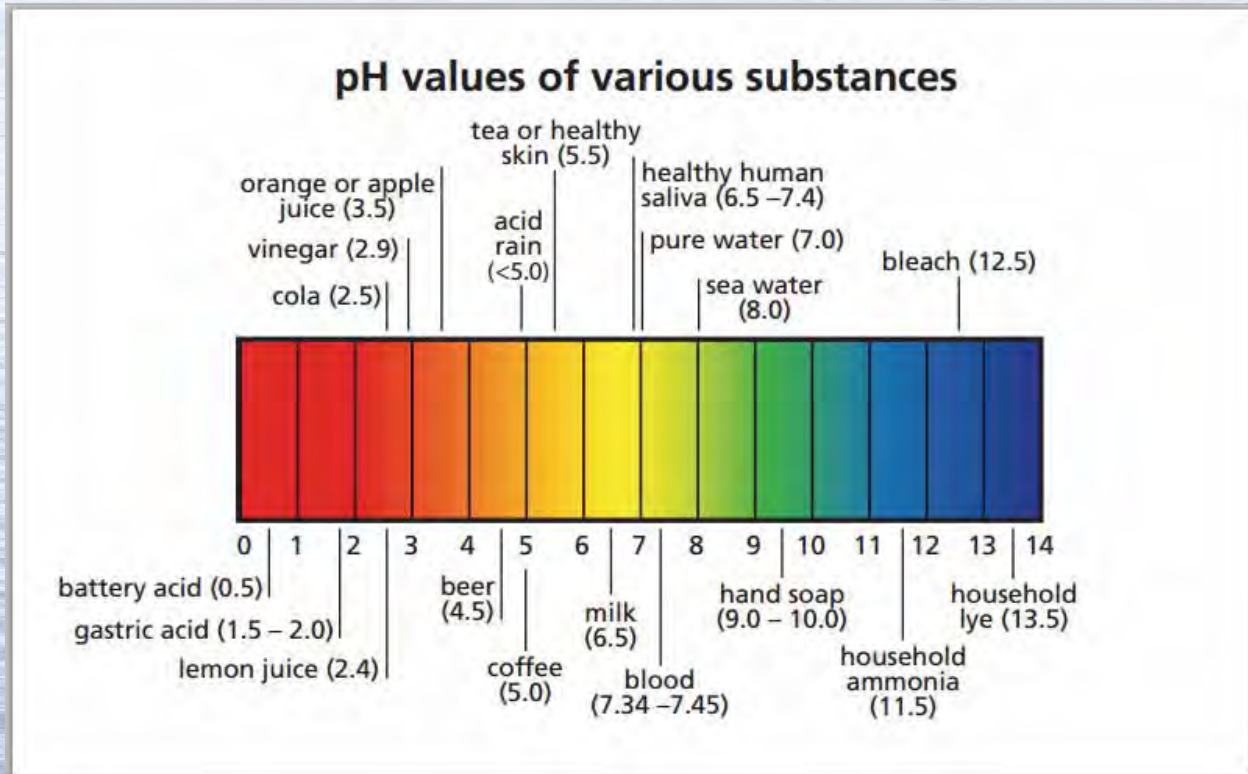




$CaCO_3$


clay
silty clay
sandy clay
clay loam
silty clay loam
sandy clay loam
loam
silt loam
sandy loam
loamy sand
sand
silt
Clay (%)
Silt (%)
Sand (%)


O Organic materials
A Topsoil
B Subsoil
C Weathered or decomposed rock (Parent material)
R Solid rock



H_2O / CO_2 / O_2 / $CaCO_3$

H_2CO_2
(Carbonic Acid)

$Ca(HCO_3)_2$
(Calcium Bicarbonate)

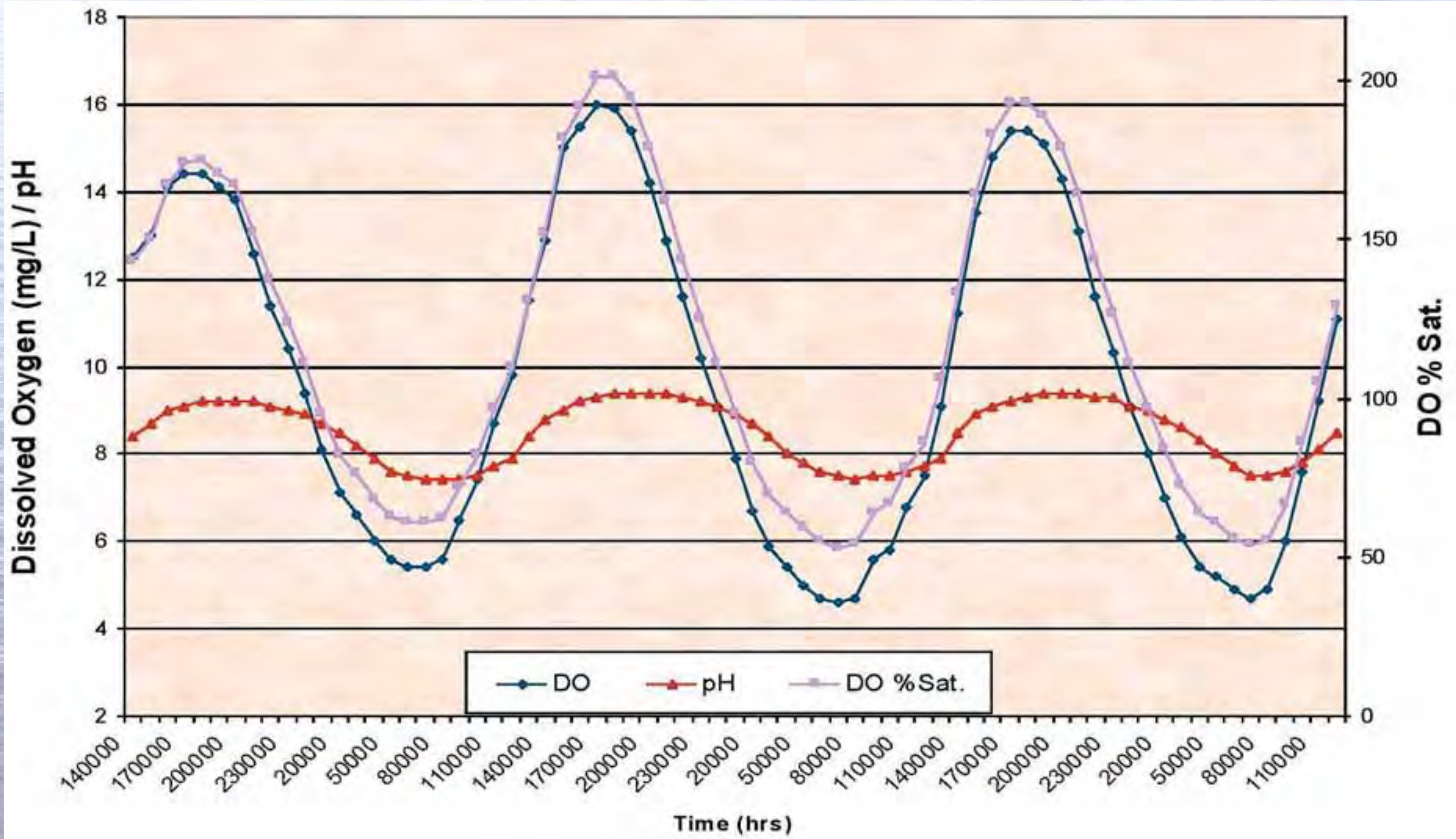
HCO_{3-}
(Bicarbonate Ion)

CO_3^{2-}
(Carbonate ion)

	pH	
Photosynthesis	↑	Uptake of CO_2 reduces carbonic acids
Respiration	↓	Release of CO_2 increases carbonic acids
Rainfall	↓	Rainfall is naturally slightly acidic

Calcium Carbonate acts as a buffer in this process

Decrease in pH (more acidic) produces more bicarbonate ions from $CaCO_3$	↑	Increase of bicarbonate ions increases pH (more alkaline)



Dissolved Oxygen (mg/L) / pH
DO % Sat.
Time (hrs)
DO
pH
DO %Sat.
18
16
14
12
10
8
6
4
2
200
150
100
50
0
140000 170000 200000 230000 20000 50000 80000 110000 140000 170000 200000 230000 20000 50000 80000 110000 140000 170000 200000 230000 20000 50000 80000 110000

How does the type of lake impact the fishing?

How does the type of lake impact the fishing?

Simple Question Right?

- Two primary types of Lakes, several subsets
- Natural Lakes - Kettle Lakes oxbows, backwater
- Artificial Lakes -Created by flooding land behind a dam, impoundment or reservoir, pond, etc.
- Each subtype has unique properties that require a mixed bag of fishing techniques and high level of skill to be successful

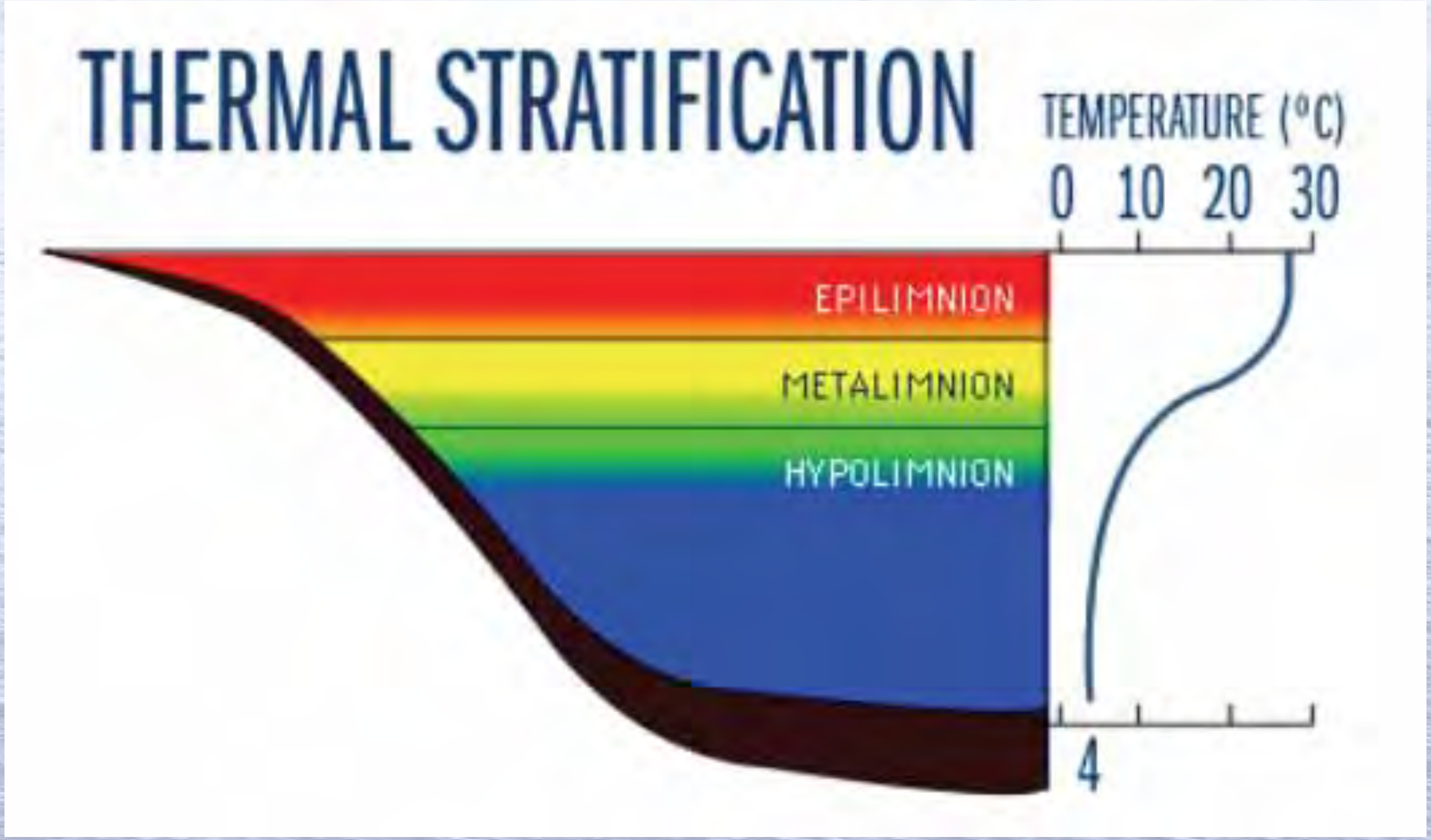
- Water Temperature
- Feeding Habits
- Life Cycles

Groups of Fish & Temperature

- Temperature exerts a major influence on water quality, biological activity and growth rates
- Governs the kinds of organisms that reside
- Fish, invertebrates, & other aquatic species all have a preferred temperature range.
- As temperatures increase above or decrease below this preferred range, the number of individuals decreases

Warm-water, Cold-water, and Cool-water Species

- **Warm-water fish species:** Adapted to a wide range of conditions. Largemouth bass, bluegill, catfish, crappies and sunfish; thrive best when water temperatures are around 80 ^{0}F
- **Cool-water fish species:** Adapted to warmed temps than coldwater species, but thrive best in water temperatures that range in the 60's and 70's ^{0}F .Muskellunge, northern pike, walleye, and yellow perch are among the most common cool-water game fish species.
- **Cold-water fish species:** Require cold water year round to survive. Cold-water species prefer water temperatures that are in the 50 to 60 ^{0}F.



- **Dissolved oxygen, pH, nutrient (mg/L), and fish species can be highly variable between layers**
- **Upper and middle/lower layers can function as 2 separate lakes**
- **Some lakes offer opportunities to catch warm and cool season species from within the same lake, due to depth and stratification**

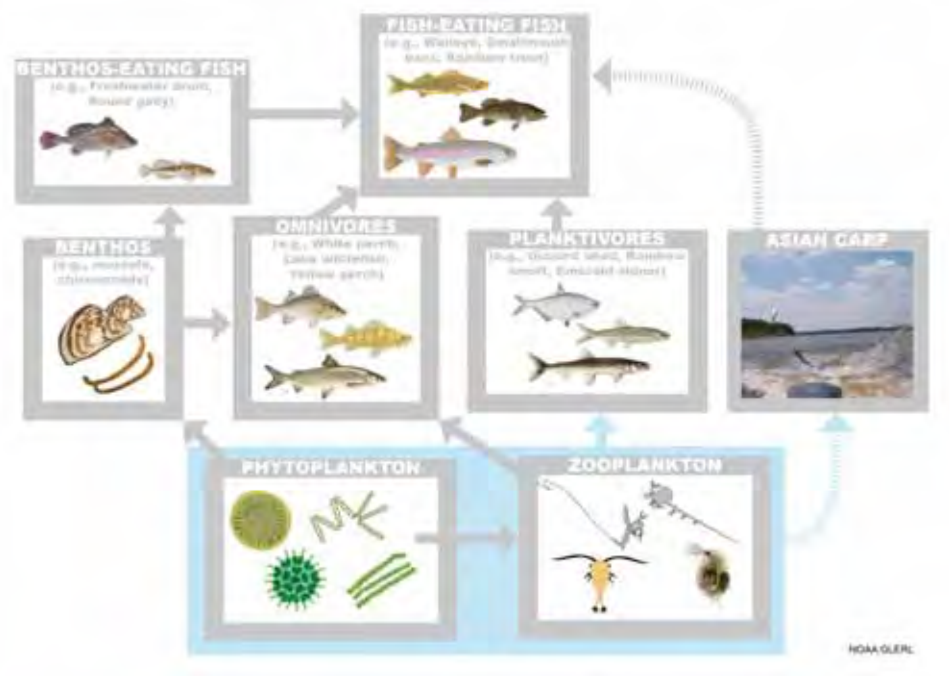
Power Plant Cooling Lakes

- Built to cool the electric generators
- Warmer later in the year and earlier in the spring =Longer feeding and growing seasons
- Water is the warmest near the plant and cools as it goes around the lake
- Generating activity = how warm the water is flowing from the plant
- Can be detrimental in summer (thermal loading)
- The IDNR fisheries biologists stocking the right species of fish, managing adequate food sources and monitoring weed growth.
- Winter: Powerton Lake, Clinton Lake, Lake Springfield, Lake of Egypt, Sangchris Lake, Newton Lake, Coffeen Lake, and Baldwin Lake
- Spring: Braidwood Lake and LaSalle Lake

Feeding Habits

- Bony **fishes** = diverse range of food preferences. planktivores; carnivores; omnivores; detritivores; herbivores?

- Each species fits into various "feeding guilds" and is placed at various trophic levels in the food chain



Feeding Habits

- Tend to concentrate where food is plentiful and easy to acquire
- Primarily Generalists and Opportunistic; hatching insects, migrating frogs, inflows of worms from small streams, fish eggs, and schools of baitfish
- Weather, moon phase, and season play a HUGE role

Feeding Habits - Day or Night?

- Generally prefer low light conditions morning/evening compared to bright sun of midday. Especially in clear lakes
- Cloud cover creates a twilight of its own and may encourage fish to bite.
- Murky lakes are less influenced by light penetration and are less likely to be spooked.
- Catfish, bass, crappie and many other species of fish will bite day or night; however fishing pressure or heavy recreational use can shift feeding to night time in some lakes.
- Big fish seem to be less selective and easier to catch when it is dark.
- Fishing at night is difficult even for experienced anglers, but once mastered can be very rewarding!

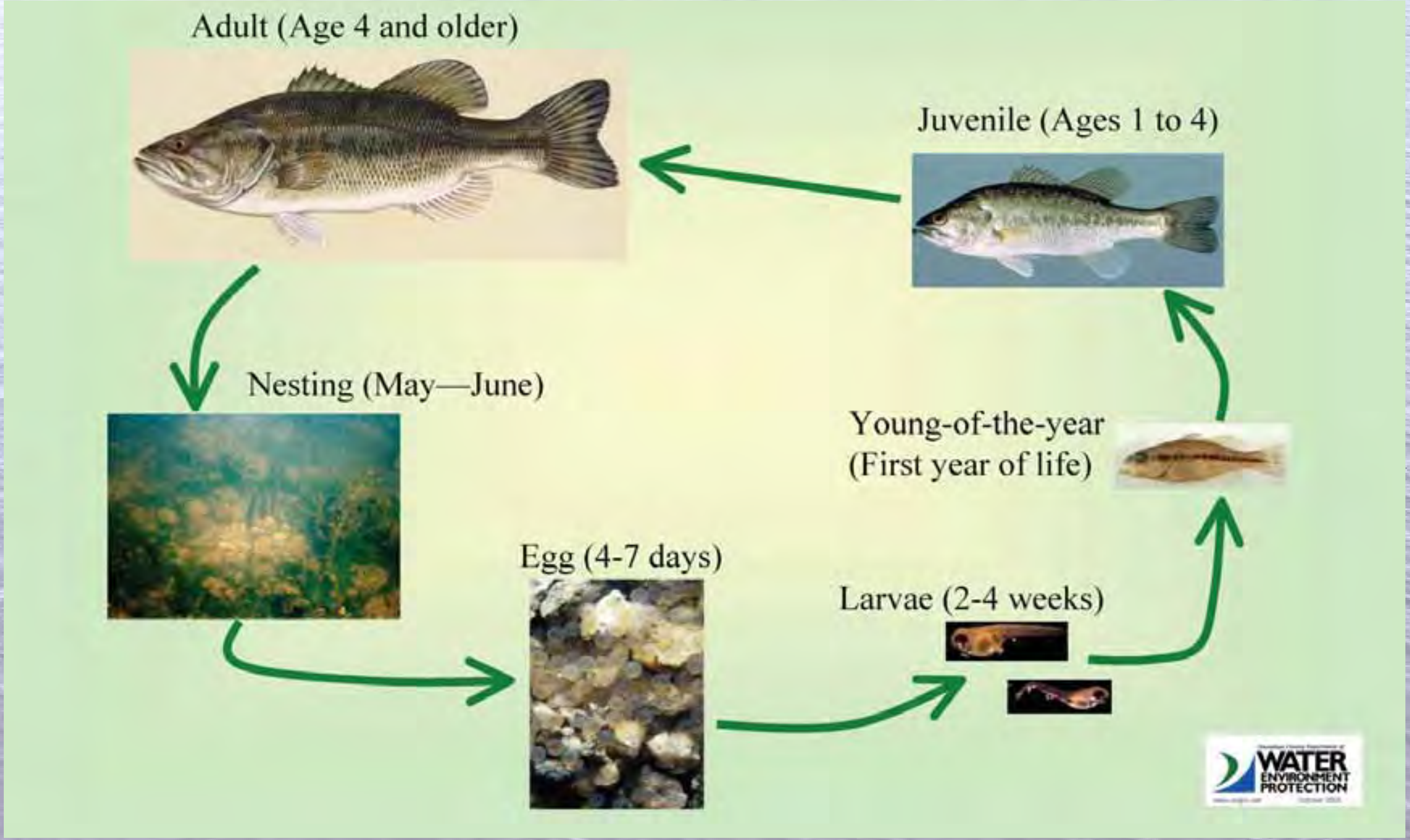
Life Cycles by Regions and Lake Types

- Fish need to survive and grow large enough to reproduce.
- Fish that survive to adulthood use a range of strategies to ensure successful spawning.
- Each species favors certain habitat types for spawning; larval fish development ; and YOY.
- Use shallow water habitat, during some part life cycle.
- Particularly spawning hab
- Some, prefer wetlands with aquatic vegetation, shallow rocky reefs
- Provide rich areas for food and protection for the eggs and the fry

Life Cycles by Regions and Lake Types

- **Eggs:** Most eggs do not survive ; Larval: Larval fish live off a yolk sac until it is fully absorbed
- **Fry:** Fry are ready to start eating on their own and are generally considered fry during their first few months to just less than one year in some species.
- **Juvenile:** The time fish spend developing from fry into reproductively mature adults varies among species. Most fish do not survive to become adults.
- **Adult:** When fish are able to reproduce, they are considered adults. The time it takes to reach maturity varies among species and individual fish. Fish with shorter life spans reach maturity faster.
- **Spawning:** Female fish release eggs into the water (water column or into a nest) and male fish fertilize eggs by releasing milt. Not all eggs are fertilized. Some fish spawn each year after reaching maturity, others spawn at intervals, or once then die
- **Threats to Spawning:** Changes in water temperature and oxygen levels, flooding or sedimentation, loss of habitat

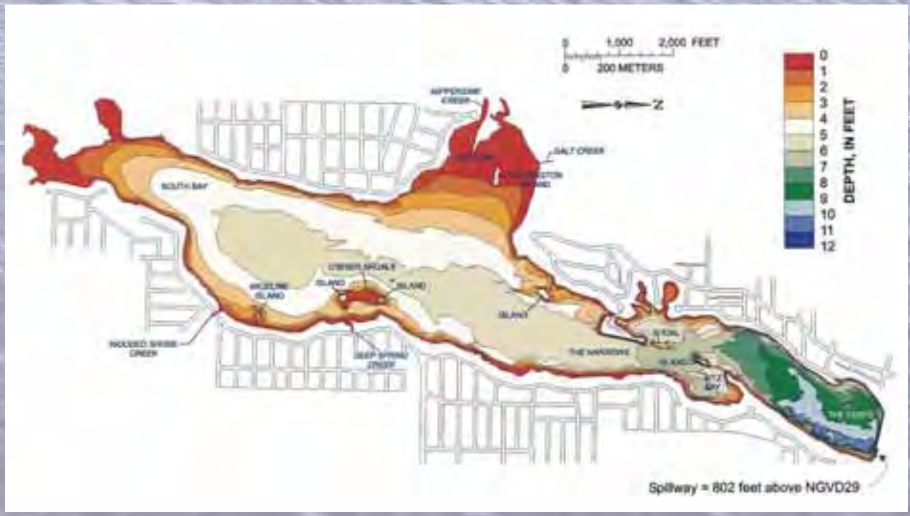
Life Cycle of the LMB



How does the shape and formation of the lake impact it?

Lake Morphometry

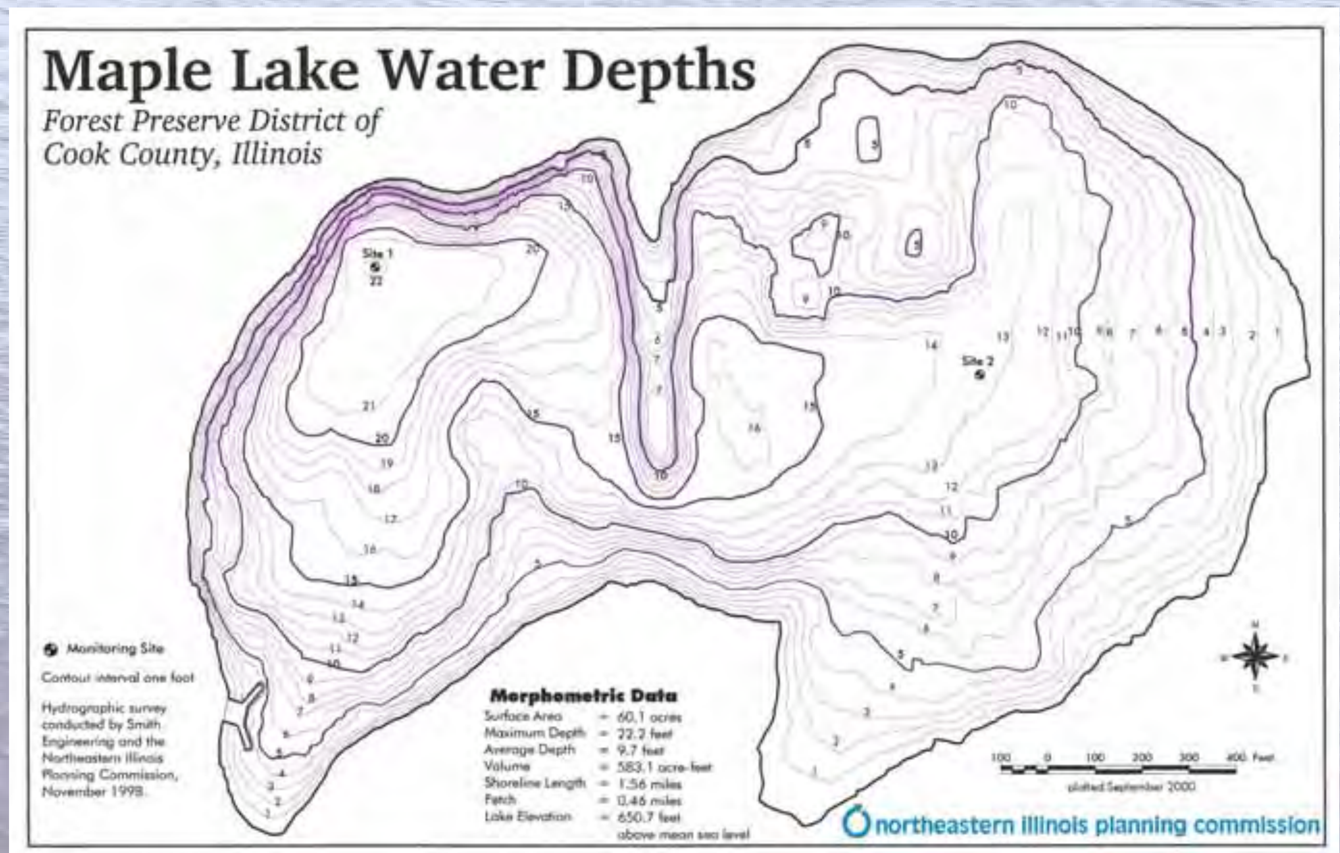
- Along with watershed size, slope, and surrounding land uses, lake ***morphometry*** (physical characteristics such as lake size, depth, and volume) adds important factors toward understanding sedimentation rates, hydraulic residence time and flushing, and subsequent effects on lake quality



Lake Morphometry

bathymetric maps are a great source of information

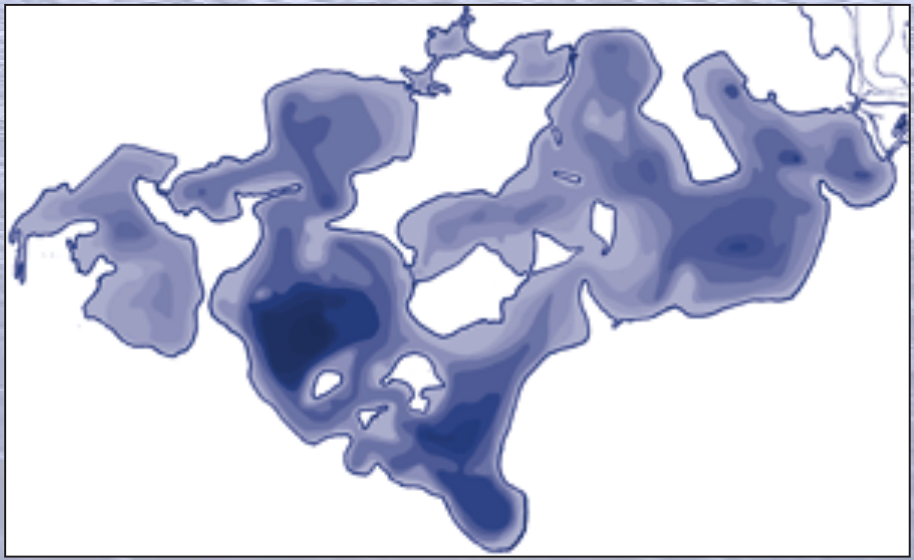
- Surface area
- Volume
- Maximum depth
- Mean (Avg) depth
- Shoreline length
- Lake shape
- Maximum length (fetch) & orientation of main axis



The size and shape of the lake matter

- Shoreline development
  - Habitat
  - Aquatic plants
  - Water movement
  - Erosion potential
  - Privacy for people

- **Here's 40 acre Ice Lake compared to 14,500 acre Lake Minnetonka**



Lake Shape and Shoreline Length

Round Lake

Area = 100 acres

Shoreline = 7,400 feet

Crooked Lake

Area = 100 acres

Shoreline = 12,000 feet

Lake Shape & Orientation and Wind Fetch

Wind Direction

- long fetch = more internal mixing

Wind Direction

- short fetch = less internal mixing

Shoreline Slopes, Soils, and Erosion Potential

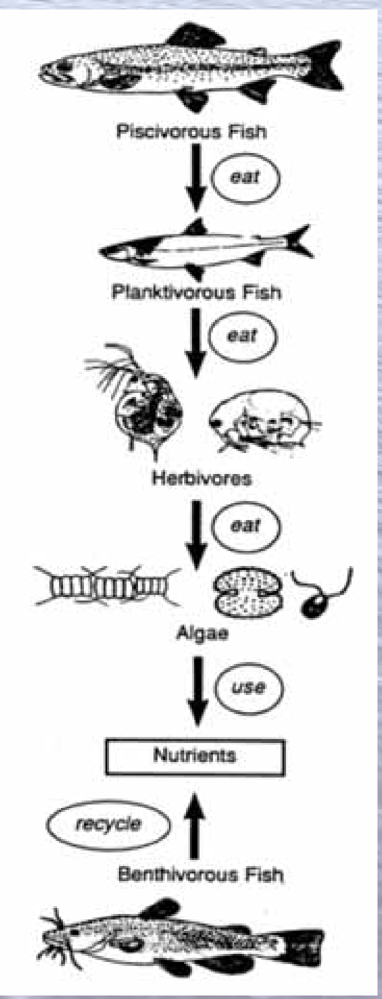
- Natural lakes

Shoreline Slopes, Soils, and Erosion Potential

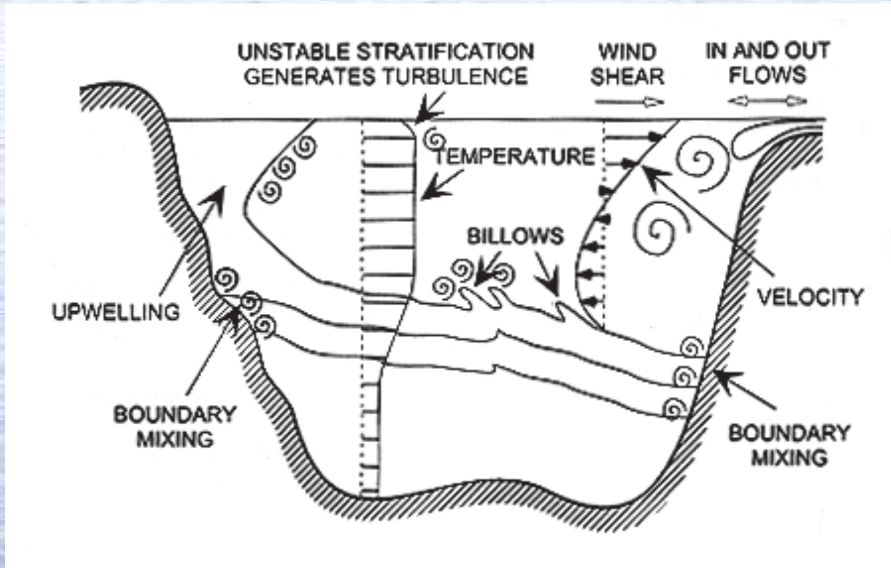
- Man-made lakes

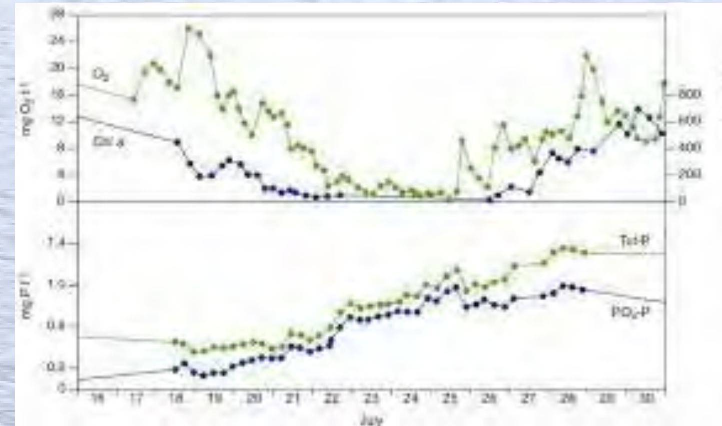
Physical Properties & Dynamics Summary

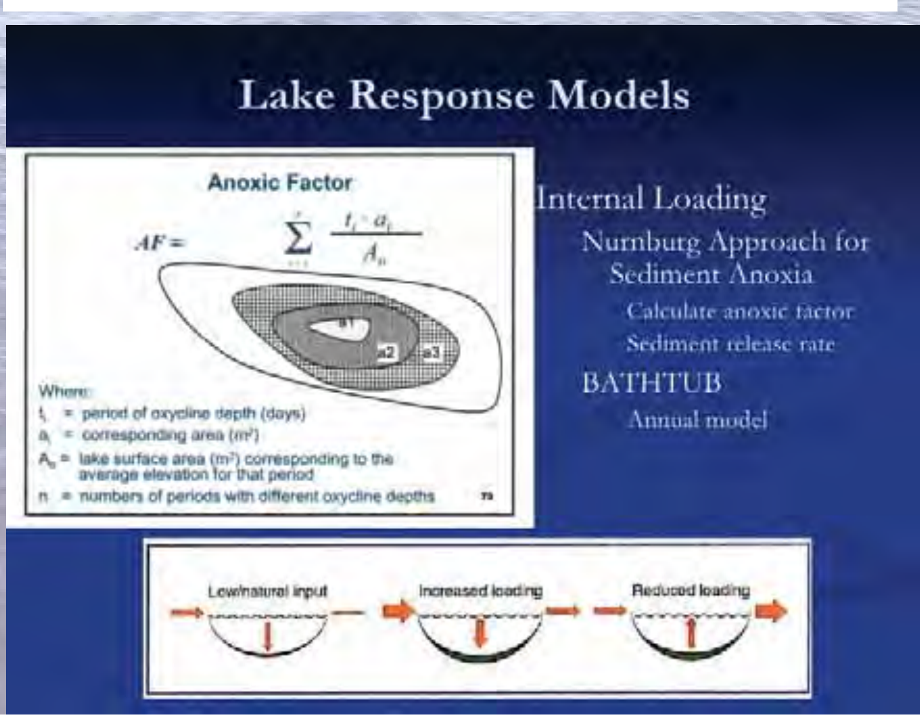
- Lake Origin
  - Natural
  - Man-made
- Lake Watershed
  - Size
  - Land cover / use
    - hydrology
    - pollutant loading
- Lake Morphometry
  - Size
  - Shape
  - Depth
  - Volume
    - wind fetch
    - shoreline length
    - mixing & stratification
    - productivity

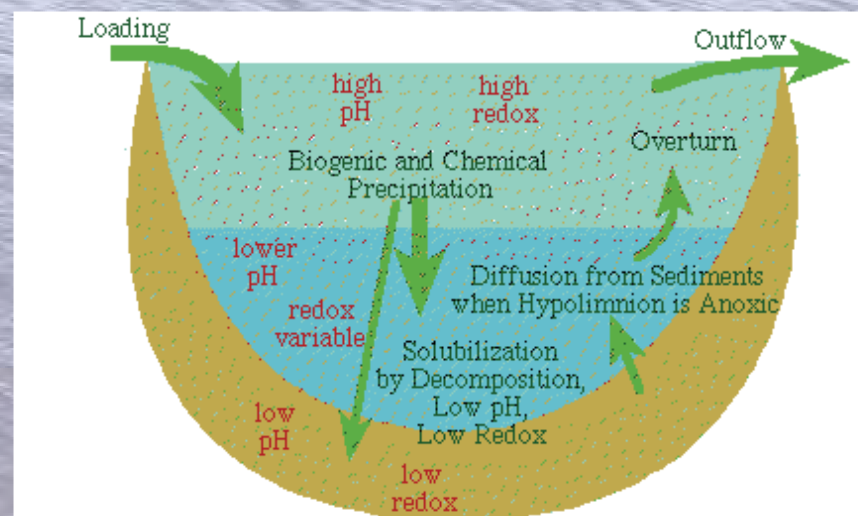


What are limiting factors?





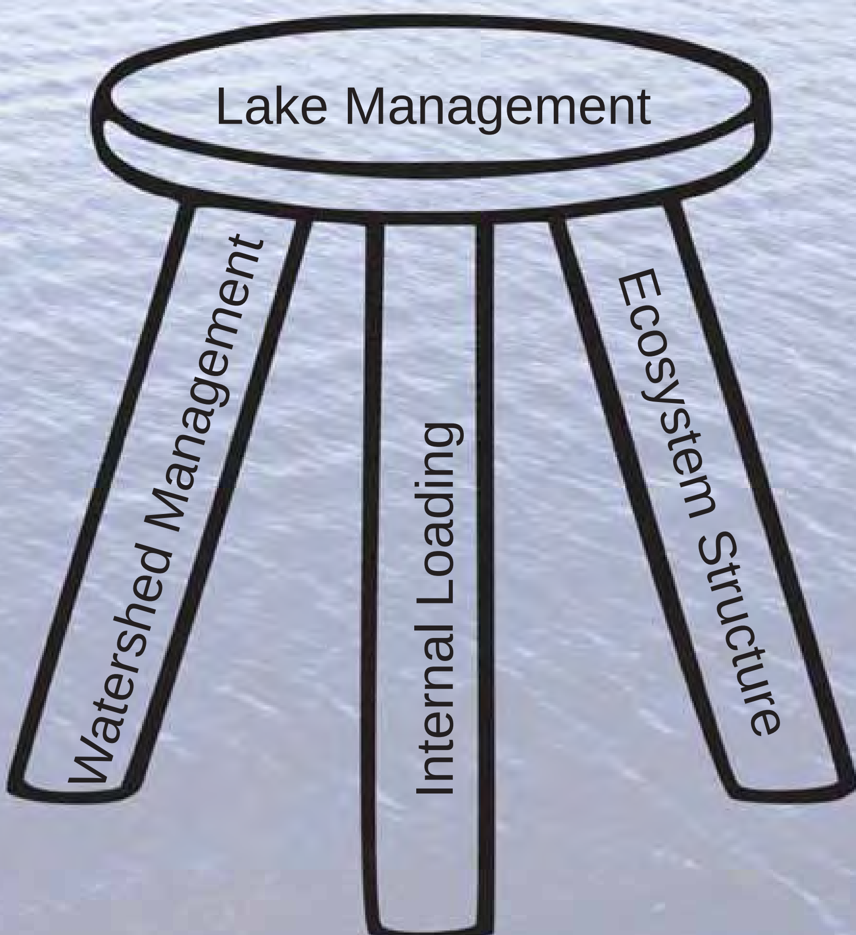




Movement of Nutrients Within a Lake Ecosystem

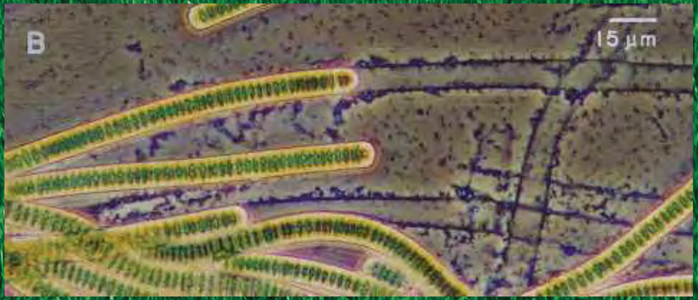
Lake Management

- **The 3 Legged Stool**



Nutrients - where do they come from?

- External
  - Origin and Morphology
  - Watershed
    - Lawns, fields, STPs, bank erosion, septics, etc.
  - Atmospheric



- Internal
  - Recycling

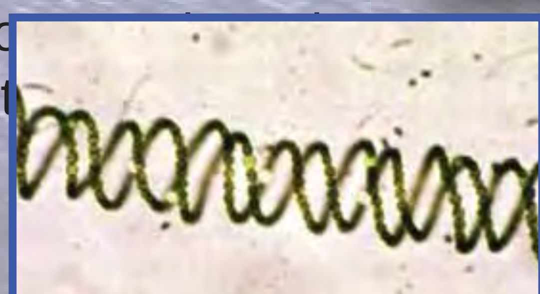
- Nutrient Limitation

Total N : Total P

>15:1 = Phosphorus limited

<10:1 = Nitrogen limited

- – Phosphorus limited lakes
  - Most lakes
- – Nitrogen limited lakes
  - Not as co
    if present



Internal Loading

H2S, PO4, Fe

Alternative Stable States – “The Shallow Lake Flip”

- Plant vs Algal Dominated

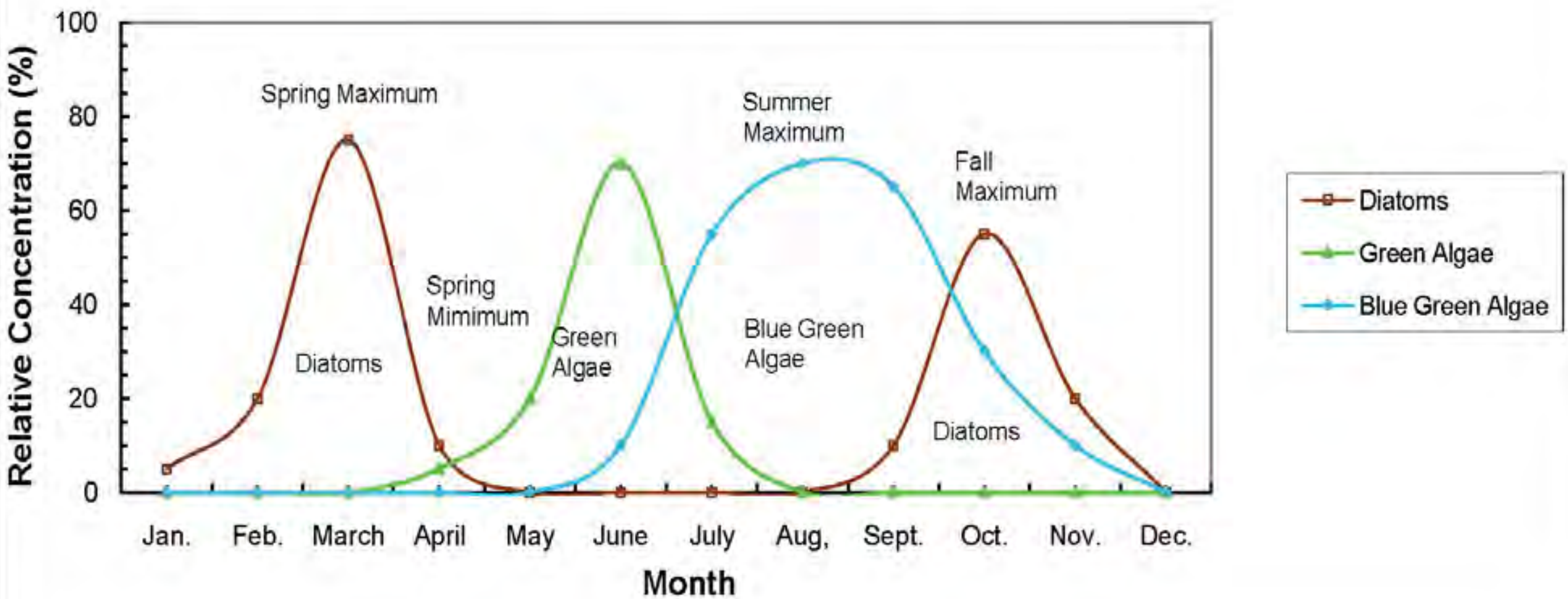
HABS vs. Green Algae

BLUE-GREEN ALGAE

FILAMENTOUS ALGAE

DUCKWEED

Seasonal Growth Patterns in Phytoplankton



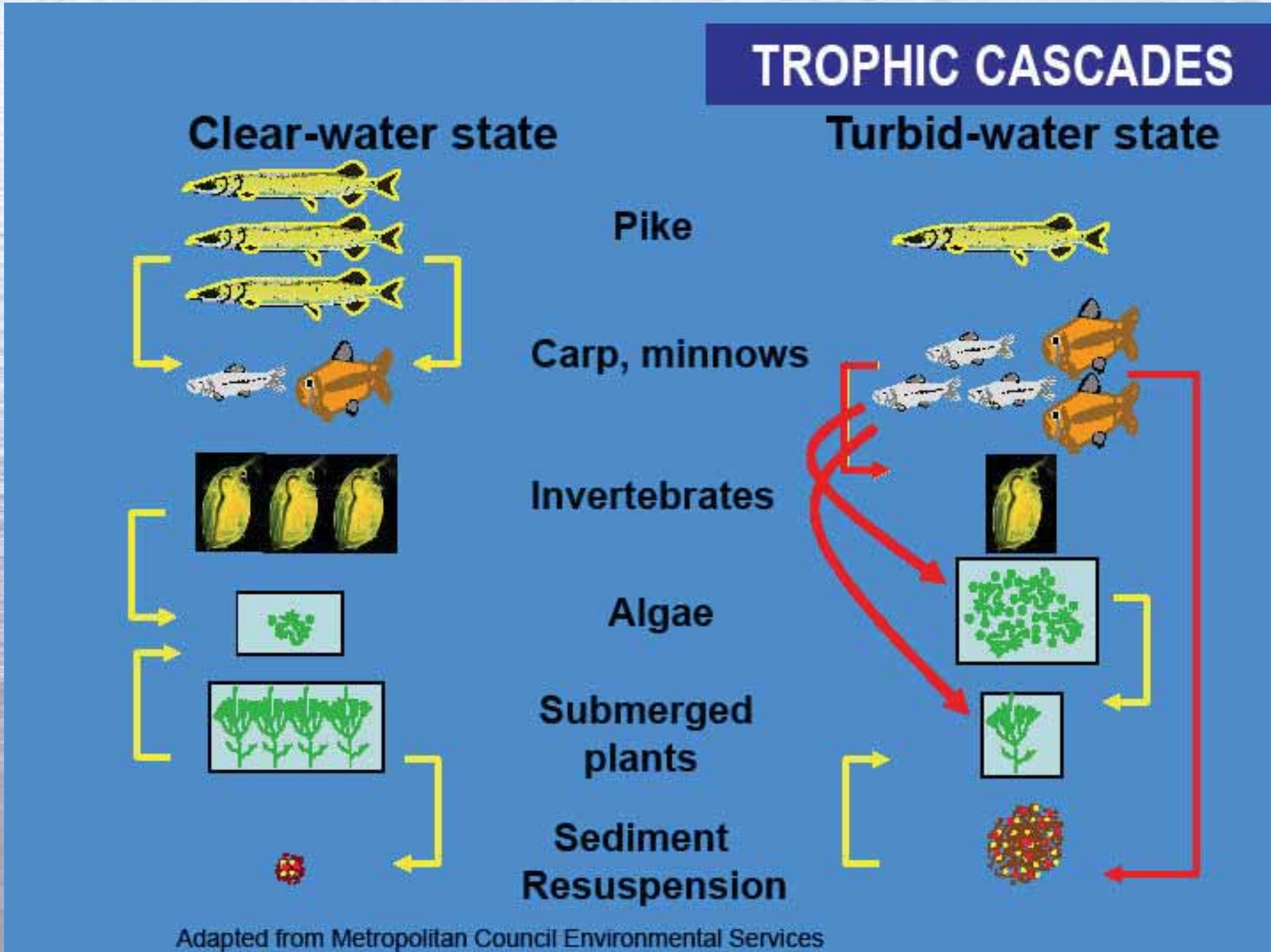
Harmful Algae Blooms (HABs)

The Primary Cyanotoxins and their Health Effects

<table>
<tr><th>Cyanotoxins</th><th>Health effects</th><th>Most common cyanobacteria producing toxin</th></tr>
<tr><td>Microcystin-LR</td><td rowspan="2">Abdominal pain
Vomiting and diarrhea
Liver inflammation and hemorrhage
Acute pneumonia
Acute dermatitis
Kidney damage
Potential tumor growth promotion</td><td>Microcystis
Anabaena
Planktothrix
Anabaenopsis
Aphanizomenon</td></tr>
<tr><td>Cylindrospermopsin</td><td>Cylindrospermopsis
Aphanizomenon
Anabaena
Lyngbya
Rhaphidiopsis
Umezakia</td></tr>
<tr><td>Anatoxin-a group</td><td>Tingling, burning, numbness, drowsiness, incoherent speech, salivation, respiratory paralysis leading to death</td><td>Anabaena
Planktothrix
Aphanizomenon
Cylindrospermopsis
Oscillatoria</td></tr>
</table>


Miracle-Gro
LANT FOOD


SEP 28 2001



TROPHIC CASCADES
Clear-water state
Turbid-water state
Pike
Carp, minnows
Invertebrates
Algae
Submerged plants
Sediment Resuspension
Adapted from Metropolitan Council Environmental Services

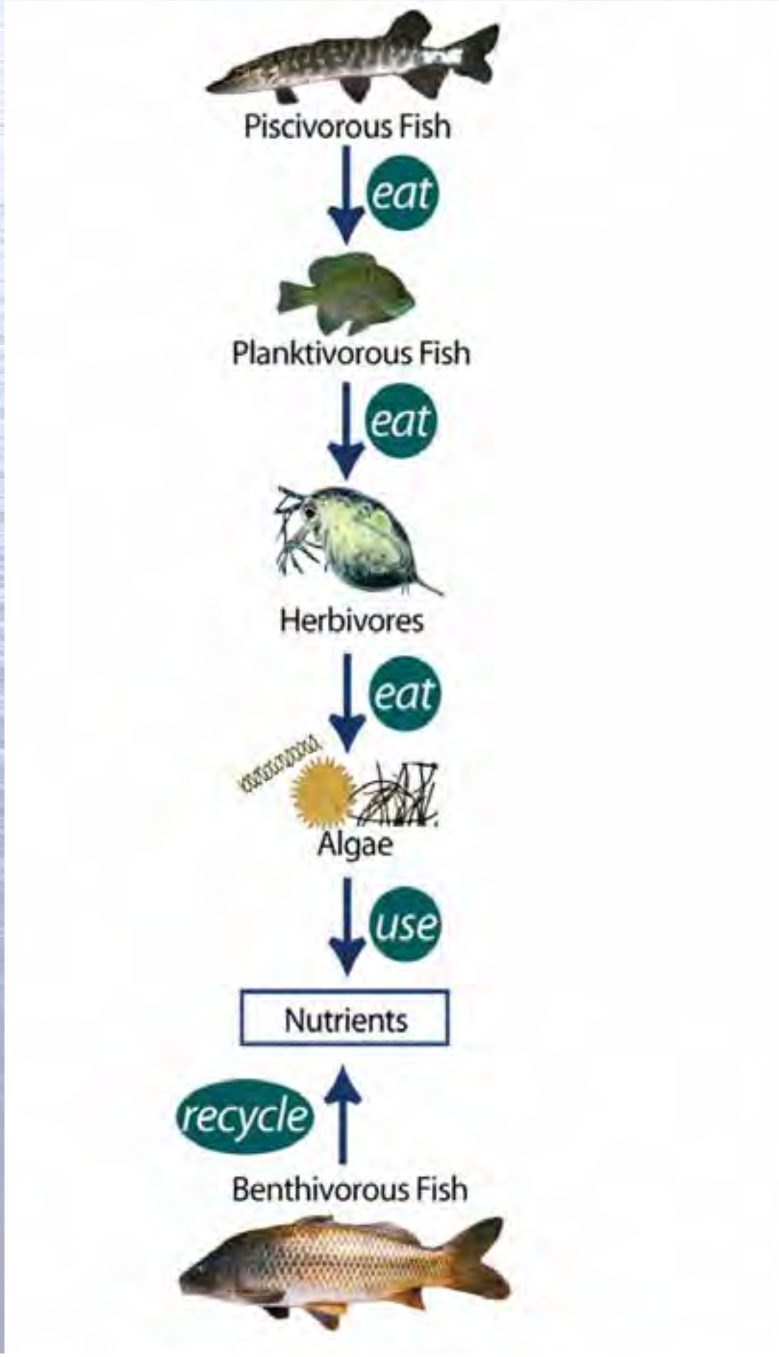
Ecosystem Structure

- Total Phosphorus equal inside and outside enclosure

Clear water, plants, NO panfish

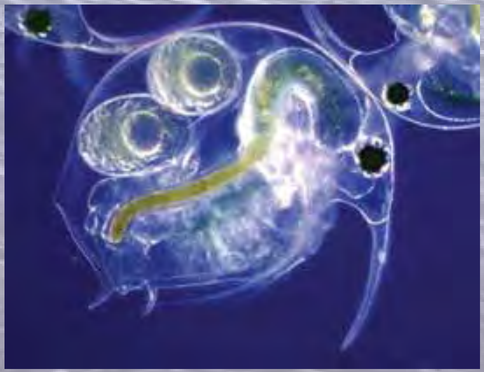
Turbid water, algae, LOTS of panfish

Food Chain



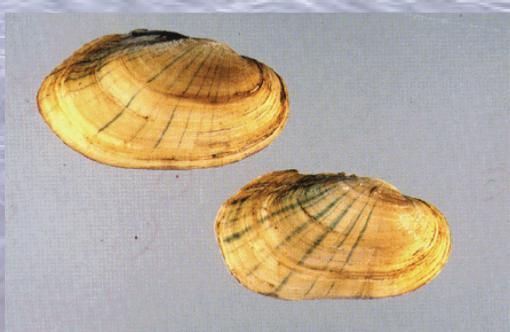
Piscivorous Fish
eat
Planktivorous Fish
eat
Herbivores
eat
Algae
use
Nutrients
recycle
Benthivorous Fish

Plankton



Aquatic plants

Aquatic plants

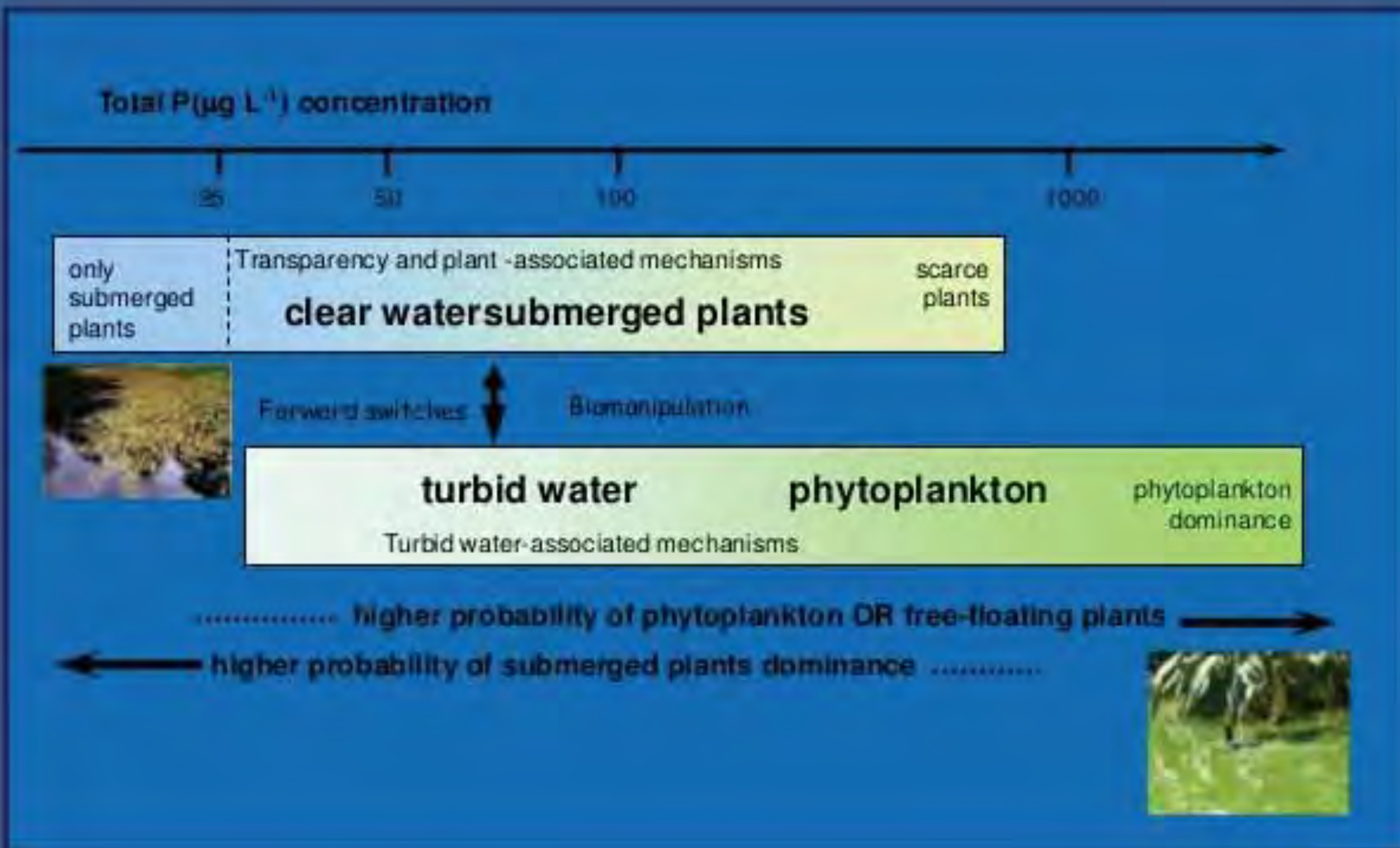


What is the interaction between fish, water clarity, and aquatic plants?

Fish, Water Clarity, and Aquatic Plants

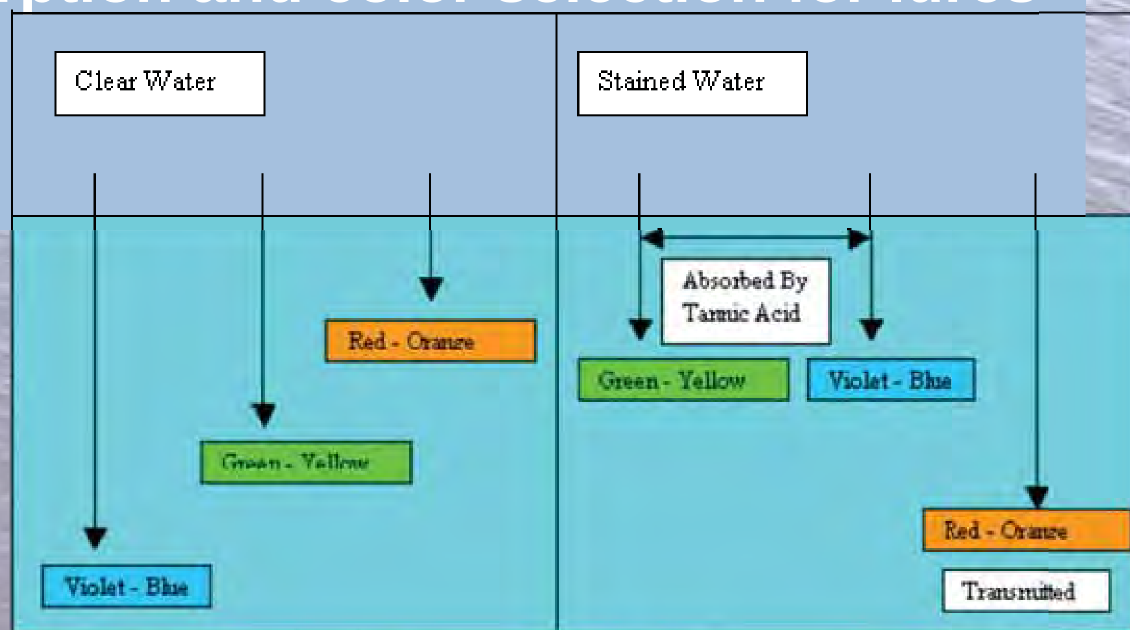
- **Fewer plants = less food for many aquatic species, less oxygen, less niche habitat and cover;**
- **Turbidity blocks the sunlight that plants need to produce oxygen for fish and other aquatic life**
- **Type and quantity of fish species often driver behind turbidity and aquatic plants**
- **High turbidity = algal dominated systems devoid of plants populated by “rough fish” tolerant of poor water quality**
- **Delicate balance between too much and too little turbidity – alterna**

Alternative Stable States Hypothesis



Stained Water vs Clear Water

- Stained lakes have more consistent fishing patterns and fish tend to spook much less than in clear water
- Stained lakes dark color absorbs the sun's energy better than clear water, resulting in accelerated water temperatures in the spring
- Effects light absorption and color selection for lures



Stocking Species to Offset Impacts

- **No natural reproduction**, thus they must be stocked
- Migratory species dependent on larval drift
- Water quality or habitat not “good enough” to support some life stage
- limited successful reproduction due to predation, overfishing etc.
- Species such as hybrid crappie are often stocked to augment natural populations
- Put and take fisheries for cold-water species not suited to the climate outside spring and fall

Stocking Species to offset Impacts

- **Habitat Loss**

- **Structures and vegetation reestablishment can improve habitat for various life stages important to achieving natural recruitment (both rearing and egg laying)**

- **Replacing Homogenous shorelines with a diverse mix of habitats helps**

Stocking Species to Offset Impacts

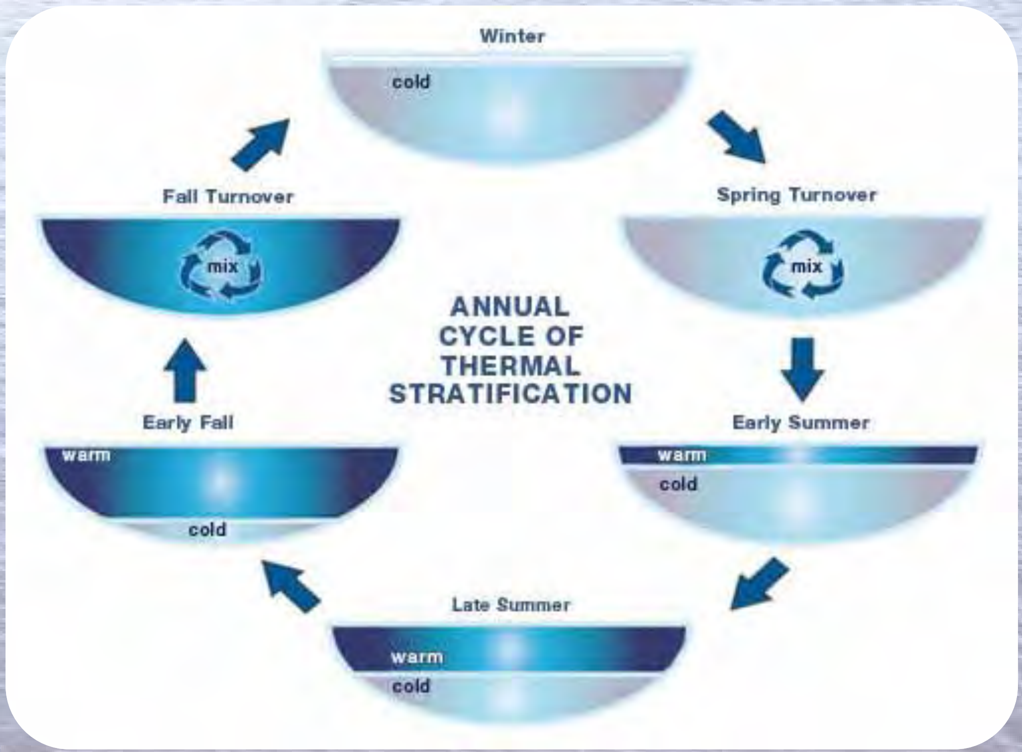
- **Turbidity**: Degrading spawning beds, affecting gill function; prevent successful development of eggs and larvae; reduce growth rate, increase susceptibility to disease, etc.
- **Predation:** Nest robbing/disturbance; Larval fish susceptibility (no cover); and invasive species can also have significant impacts and “short circuit” successful recruitment

Stocking Species to Offset Impacts

- **Impact of feeding habits on plankton**
- Trophic cascade hypotheses predict that fish will affect the structure and biomass of pelagic plankton communities
- Interrelationships within a food web can be very intricate
- Single species changes to complex food webs, can trigger a wave of change and disruption
- Ultimately leads to an impact on feeding habits-diet shifts-reduced growth
- Fish cohorts (age class) can swing dramatically and ultimately cause population extinction from the food web shifts and stocking would be required

What other cycles are going on in the lake?

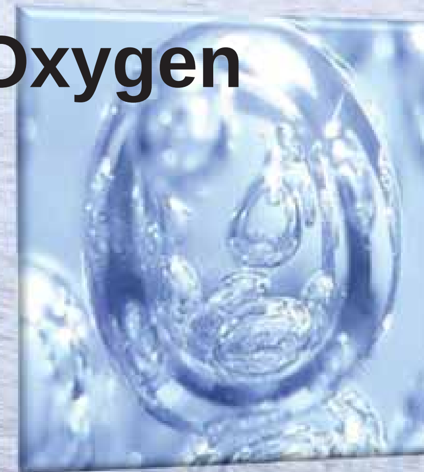
What other cycles are going on in the lake?

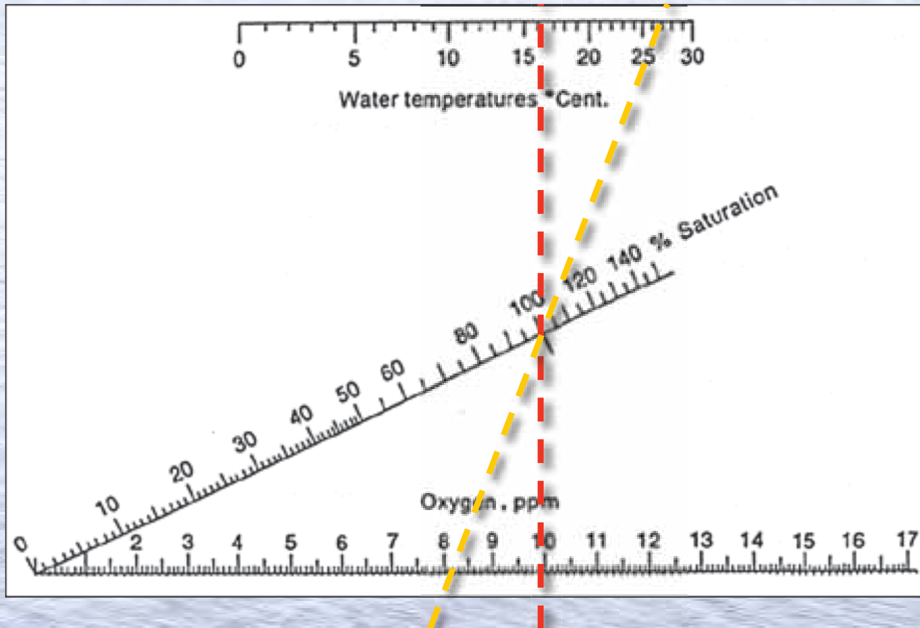


Temperature

&

Dissolved Oxygen



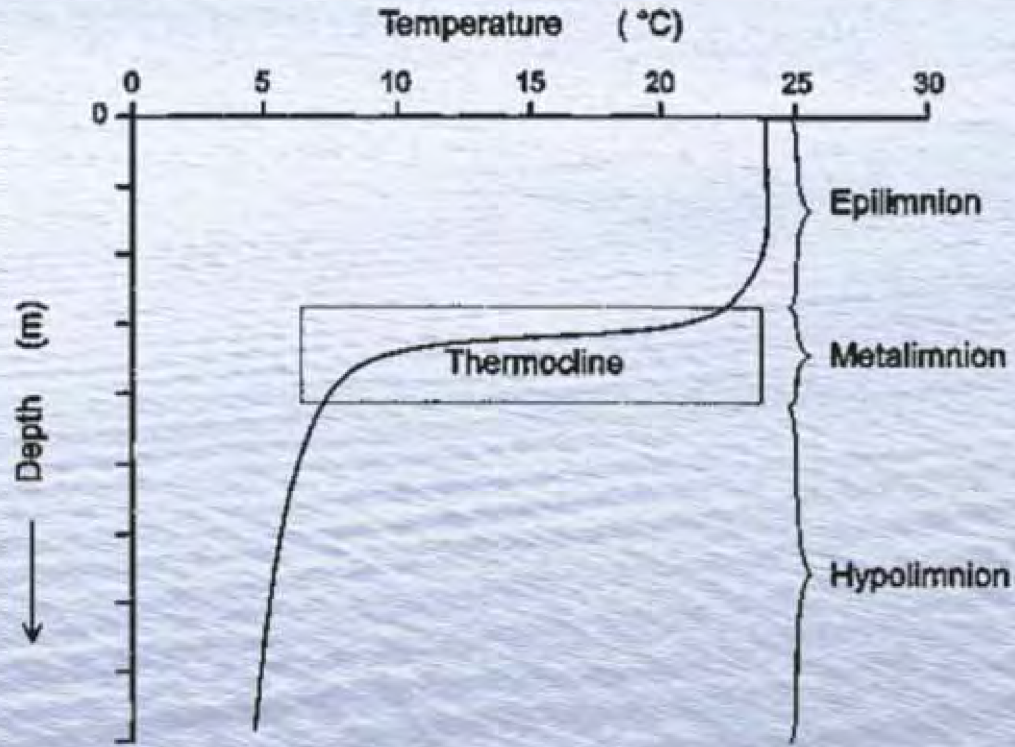


@ ~62 degrees (f) 10mg/L is @ 100% saturation

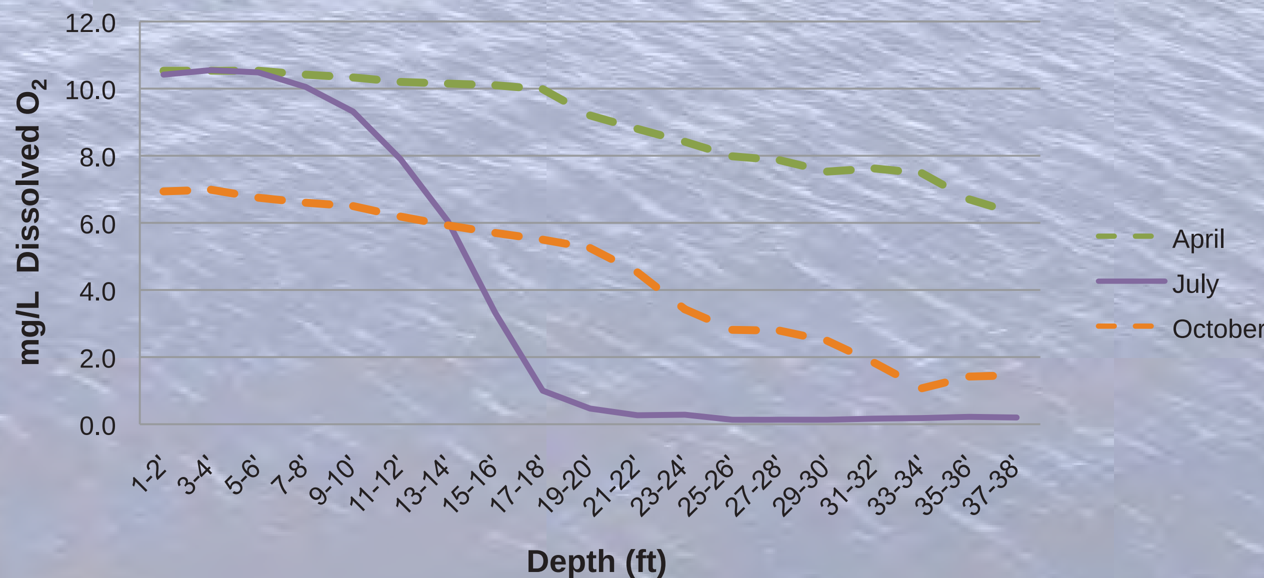
Where does the O_2 come from?

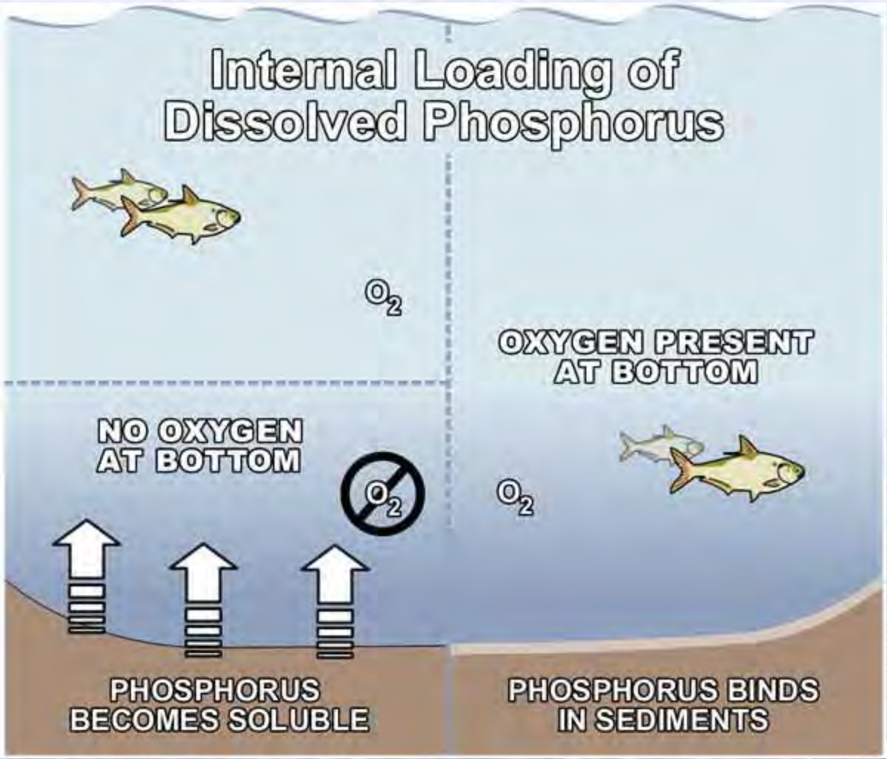
Primarily from -

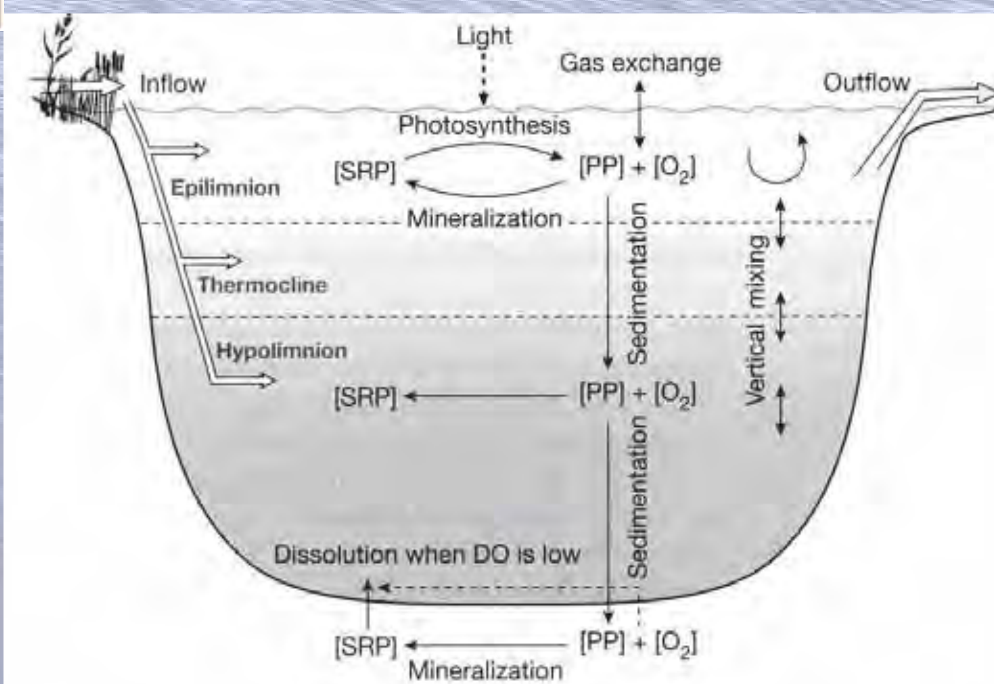
- **Atmospheric Pressure**
- **Rainfall**
- **Wind**

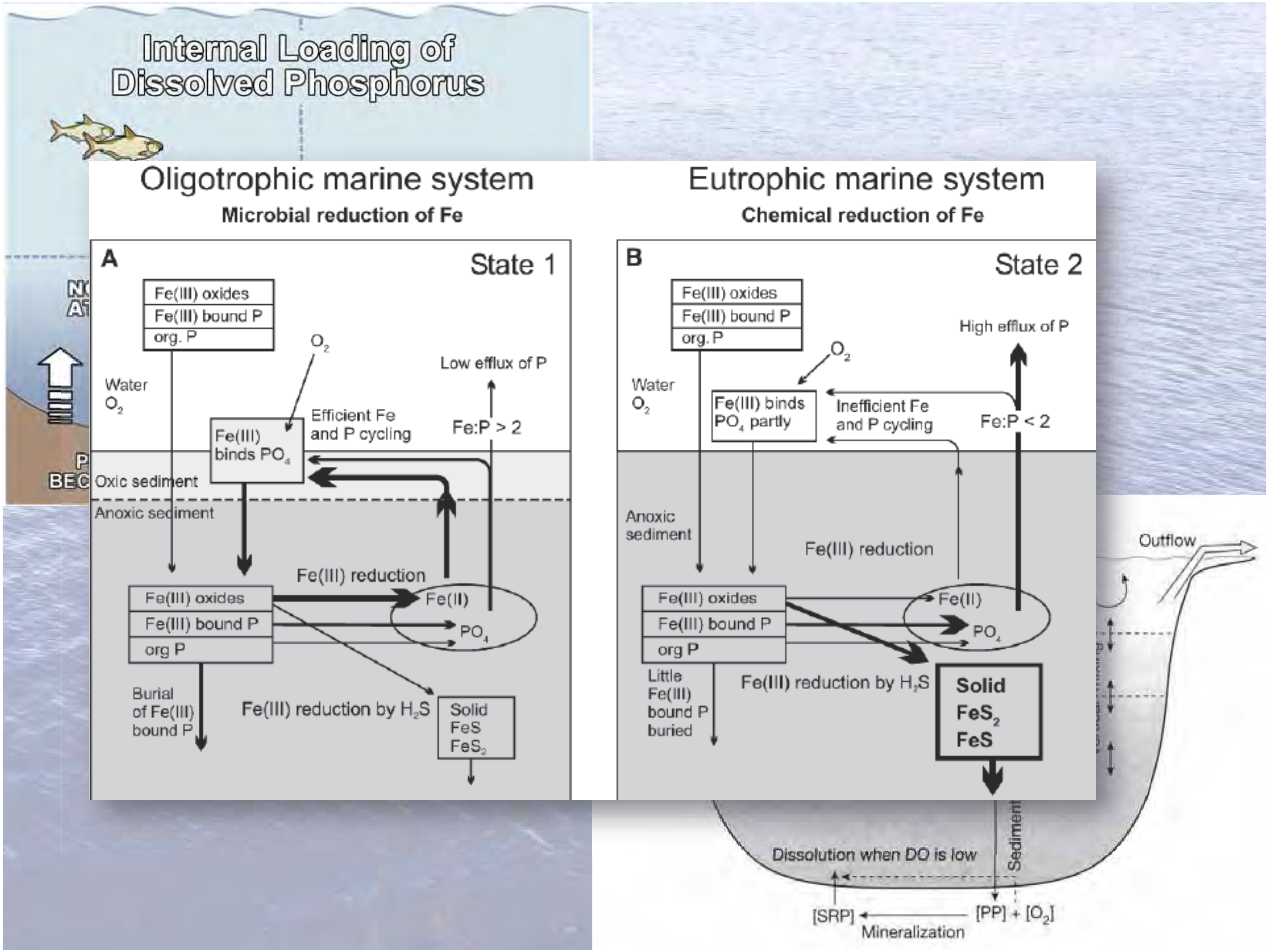


Temperature and dissolved oxygen association with turnover cycle




Internal Loading of
Dissolved Phosphorus
O2
OXYGEN PRESENT
AT BOTTOM
NO OXYGEN
AT BOTTOM
O2
O2
PHOSPHORUS
BECOMES SOLUBLE
PHOSPHORUS BINDS
IN SEDIMENTS

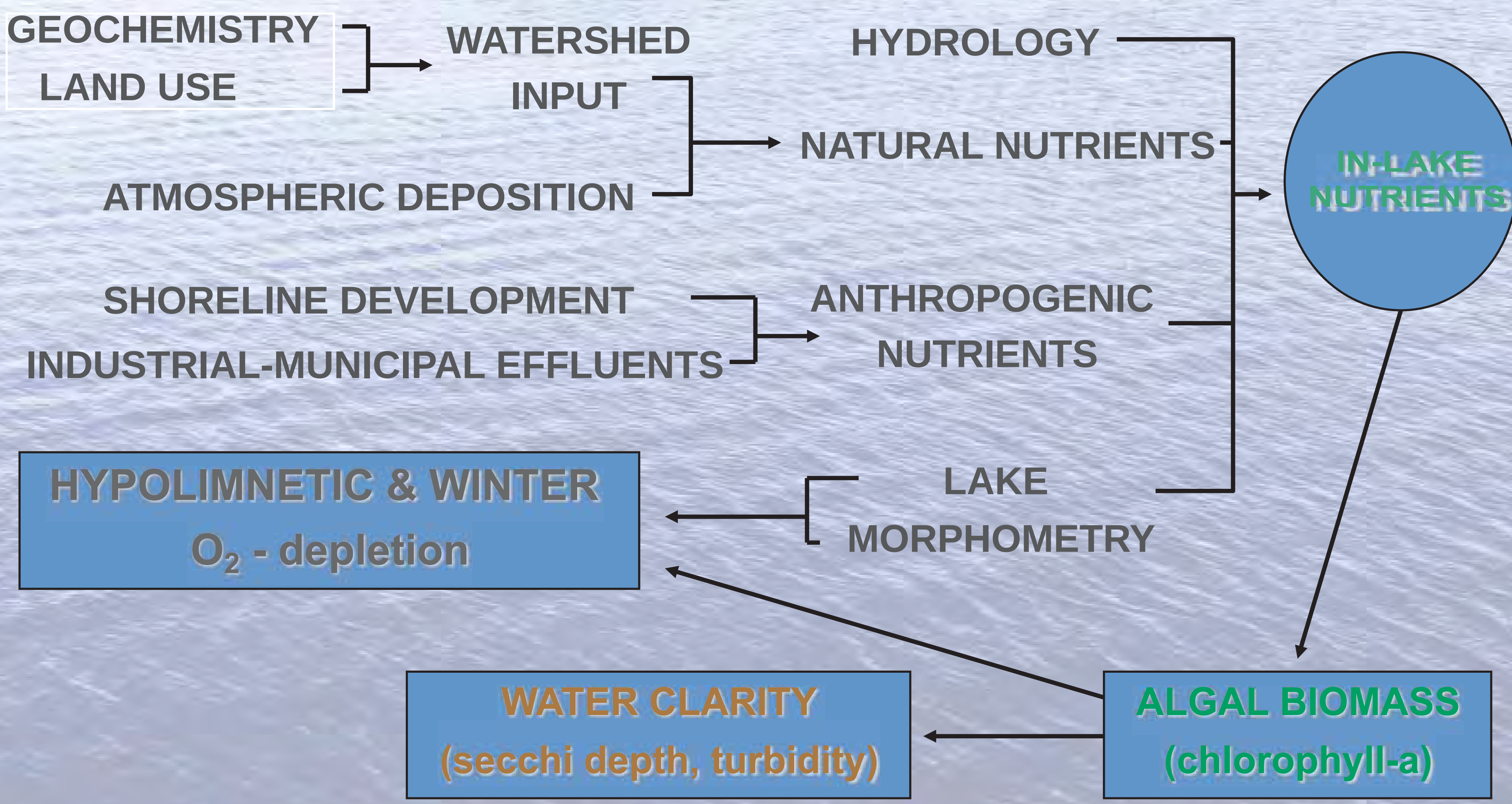

Light
Gas exchange
Inflow
Outflow
Photosynthesis
[SRP]
[PP] + [O2]
Epilimnion
Mineralization
Thermocline
Sedimentation
Vertical mixing
Hypolimnion
[SRP]
[PP] + [O2]
Sedimentation
Dissolution when DO is low
[SRP]
[PP] + [O2]
Mineralization


Internal Loading of Dissolved Phosphorus
Oligotrophic marine system
Microbial reduction of Fe
A
State 1
Fe(III) oxides
Fe(III) bound P
org. P
Water
O2
O2
Fe(III) binds PO4
Efficient Fe and P cycling
Low efflux of P
Fe:P > 2
Oxic sediment
Anoxic sediment
Fe(III) reduction
Fe(III) oxides
Fe(III) bound P
org P
Fe(II)
PO4
Burial of Fe(III) bound P
Fe(III) reduction by H2S
Solid
FeS
FeS2
Eutrophic marine system
Chemical reduction of Fe
B
State 2
Fe(III) oxides
Fe(III) bound P
org. P
High efflux of P
O2
Water
O2
Fe(III) binds PO4 partly
Inefficient Fe and P cycling
Fe:P < 2
Anoxic sediment
Fe(III) reduction
Fe(III) oxides
Fe(III) bound P
org P
Fe(II)
PO4
Little Fe(III) bound P buried
Fe(III) reduction by H2S
Solid
FeS2
FeS
Outflow
Sediment
Dissolution when DO is low
[SRP]
[PP] + [O2]
Mineralization

Thanks!

Questions?

Conceptual framework for lake water quality



(Adapted from Hutchinson 1991)